**Atmospheric
Chemistry
and Physics
Discussions**

Interactive comment on "Numerical simulations of contrail-to-cirrus transition – Part 2: Impact of initial ice crystal number, radiation, stratification, secondary nucleation and layer depth" *by* S. Unterstrasser and K. Gierens

Anonymous Referee #1

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General comment:

Since I was referee for the two papers, I give one summarising review for both: A systematic study of contrail-to-cirrus transition for a large variety of ambient conditions is presented in the two papers. The goal of the papers is to provide a help to formulate or improve parameterisations that can be used in global models to assess the radiative forcing of contrail cirrus. Though the study is of interest and the results of scientific importance, the style of the paper needs to be vastly improved to make it enjoyable

and easy to understand for the reader.

In this sense, I strongly suggest to condense the two papers, maybe merge them into one which is clear, concise and contains the most important results of the study. Otherwise I fear this work will not find many readers surviving until the end of the second article. However, I would like to encourage the authors to restructure, shorten and clear the papers.

The 'Specific comments' contain examples from Part 1 to show why it is difficult for the reader to follow, and possible solutions to make the paper more fluent. The examples and suggestions given there also hold for Part 2 of the papers. To list all places where changes are necessary is beyond the task of a referee. Last, but not least, I have some scientific concerns that are summarised in the 'Scientific comments'.

Specific comments:

- **Abstract**
  - **Part 1:** ... *'Our model shows that after a few hours the water vapour removed by falling ice crystals from the contrail layer can be several times higher than the ice mass that is actually present in the contrail at any instance.'*
  Why this is so important that you wrote it in the abstract?

  - **Part 2:** The abstract of Part 2 should be rewritten. In the present form it is confusing and the flow of reading is often disturbed by statements in brackets. The message of he paper is not clear from the abstract.

- **Structure** (exemplary Section 1):
  The contrail evolution starting with formation and then passing through different phases is introduced at several places. Contrail formation is already shortly noted in section 1.1 (*'If the ambient conditions fulfil the Schmidt-Appleman criterion...'*)

and the phases are mentioned in the beginning of section 1.2 (*'Most contrail models focus on one of the three phases of contrail evolution (jet phase, vortex phase and dispersion phase, see CIAP, 1975), ...'*.

Only in the middle of section 1.2, the different phases are shortly described, starting again with contrail formation (*'If the ambient conditions fulfil the Schmidt-Appleman criterion...'*).

I suggest to introduce a paragraph/subsection describing contrail evolution from the beginning to the end. Explain the Schmidt-Appleman criterion, the statement in paragraph 1.1 is too simplified for the article (*'Contrails form when the so-called Schmidt-Appleman criterion is fulfilled, which requires the ambient temperature to be below a certain threshold'*...) and then go through the single phases one by one. Only then describe in a new paragraph/subsection the studies you performed.

- **Figures 2, 4, 5, 6, 8, 9, 10:**

  These Figures consist each of several panels, containing 16 graphs at a time. The different linestyles and colours can be found in Table 2. It is really hard – if not nearly impossible – to extract the information from these graphs.
  It would be good to reduce the number of graphs. And it would be much better to show instead of a Table a Figure containing the legend, or, better, the legend I created to have a chance to understand your plots could probably placed in each graph.

  → See last page.

  Please be patient with your readers: they are not so familiar with your graphs to keep in mind 16 different combinations of linestyles and colours.

- **Discussions** (exemplary section 3.2.1 Width:)
  This paragraph is very hard to read. Not only that one has to find out from Table 2 the meaning of the lines in Fig.2, the author didn't mention the lines he is

discussing. Only with the legend I created for myself (see above) and by adding to the text some hints about the lines (see below) I had chance to understand this section. This needs so long time that I guess a 'normal' reader would have skipped this section and also just to try to understand Fig. 2.

'... In shear-free conditions (solid lines, left panels) the qualitative behaviour is the same for both width definitions. However, if shear is present B_{OD} starts to decrease after some time for small supersaturations (RHi =105% red lines, left panels) and the contrail becomes subvisible **(this is when B_{OD} becomes 0, I suppose, say that!!)**. *Figure 2 (bottom right) shows that visible growth of a contrail strongly depends on relative humidity and shear. Only if RHi 120% (blue lines) one can expect a substantial spreading of the visible parts at high shear rates. At small supersaturations the dilution is not fully compensated by depositional growth and increasing shear reduces the visible width (RHi =105%, red lines). At RHi =110% (green lines), the two opposing effects compensate each other more or less. Sensitivity studies using tau0 =0.03 as visibility criterion show that increasing wind shear decreases the visible width also for RHi =110%.*

The effect of temperature (which effect do you mean?) depends on relative humidity. In situations where weak contrails are present a higher temperature leads to even weaker contrails, whereas in favourable conditions contrails are broader in warmer environments. **(there are so many imprecise statements – 'weak contrails', ' higher temperature', 'favourable conditions', 'broader' – and the sentence is so long that the scientific meaning gets lost; unfortunately, there are lots of sentences like this in the paper, I highly recommend to maybe ask an experienced writer to help with formulations, straightening and reducing.)**

The overall conclusion is that at small supersaturations many contrails become invisible, but still spread **(where can I see that?? – It should be seen in the plot very clearly where the contrails become subvisible; also it should be**

stated more clearly and at a prominent place –for example in the caption of the Figure– that B_{OD} denotes the visibility for a human eye, if I understood that right). Loss of visibility does not imply a physical disappearance in such a way that all crystals have sublimated.'

  – Figure 2: Show the temperature in the left and the time in the right panels.

- **Section 4.1 Turbulent background flow**
  I think this is a section which is not essential for the paper and could be cancelled.

- **Section 4.3 Lidar**
  A good place for reductions.

- **Section 5: Discussion**
  The first two sentence: *'The results of our numerical experiments have several implications* **(Which results, which implications?)**. *The most important parameter is ambient relative humidity* **(important for what??)**. *...*

- **Section 6: Conclusions**
  I suggest to shorten the items.

- **Please avoid:**
  – *'Since the physical processes in both phases are the same ...'*
    Always be specific, in this case tell the reader what processes you mean.
  – Section titles *'Width', 'Area', Vertical structure' ...*:
    Of what? If you mean 'Contrail width', etc., then say that.
    Again: always be specific → this is an important point to improve the paper.
  – *'USGS08':*
    Repeat shortly what you adopted from this article for your study. The reader doesn't want to read first another article to understand what you have done here.

  – to parenthesise.

Scientific comments:

- I miss a discussion of the recent paper of Immler et al. (2008), ACP: 'Cirrus, contrails, and ice supersaturated regions in high pressure systems at northern mid latitudes.' Immler et al. (2008) concludes: *'The occurrence of cirrus and ISSR are closely related and our observations clearly demonstrate that cirrus and contrails are generally present where the upper troposphere is supersaturated with respect to ice. The majority of persistent contrails were embedded within pre-existing cirrus. This is an important result for assessing the impact of aircraft exhaust on climate.'*
  The observations of this paper suggest, that heterogeneous freezing –which is turned off in the study presented here, though the model contains heterogeneous freezing– takes place in ISSRs and the contrails coexist with thin cirrus.

  Though I understand that it is necessary to show the contrail properties and evolution without any background, I also think that realistic studies including the cirrus are also necessary. To estimate the impact of persistent contrail on climate, it should be discussed to which extent the properties of especially the thin subvisible contrails are comparable with those of surrounding cirrus.

- There is a long discussion (page 14928) of the influence of synoptic-scale or mesoscale motions –both not treated in the present study– on the evolution of the contrails, stating that these motions *'... have a major effect on contrail-cirrus evolution.'* The discussion ends with the sentence *'To study synoptic effects is the topic of future research.'*

- How reliable are the results of the present simulations when neglecting realistic scenarios? Is a *'.. help to formulate or improve parameterisations that can be used in global models to assess the radiative forcing of contrail cirrus '* provided by the numerical simulations performed in this study?
These questions have to be carefully addressed in a revised version of the paper(s).

RHi (%)		T (K)	shear s $(10^{-3} s^{-1})$
105	——	209	0
110	··········	212	2
120	– – – –	217	4
130	–·–·–·–	222	6

Fig. 1.