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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Three-dimensional numerical simulations of the evolution of a contrail and its transition into a contrail-cirrus" *by* R. Paugam et al.

Anonymous Referee #1

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General Comments:

The presented numerical study treats the contrail evolution from the vortex phase until the early diffusion regime (at around 30min). The high-resolution 3D-modeling approach allows studying the dynamical details of the flow field and its impact on the contrail microphysics. It is the first time, that a contrail study covers the dynamic issues (vortex instability, baroclinic torque, atmospheric dispersion) in such a depth over such a long simulation time (which is achieved by a chain of 2 or 3 sub-simulations).

Thus I have no major concerns and recommend publishing the manuscript in ACP. Nevertheless I think the study can be improved by further analyzing the simulation

data and discussing the microphysical quantities in more detail in Section 3.

Specific Comments:

Title and Abstract:

Although the term contrail-cirrus is not uniquely defined in the literature, I think a 30min-contrail is still line-shaped (especially as you study a shear-free case) and thus should be referred to as "contrail". Usually it takes up to 30min until line-shaped contrails become detectable on satellite imagery, so I would not use the term "contrail-cirrus", as they are distinguishable. To avoid misunderstandings, could you please mention the maximal age of the contrail in your simulation or indicate that your simulation stops at the early diffusion regime. The next point is more a philosophical question. Does the lifetime of a contrail specify only the time span until you start calling it contrail-cirrus. I would prefer that "contrail lifetime" also incorporates the contrail-cirrus regime. Line 20: The last statement is too general. Does it hold for all shear values and also lower supersaturations? Please explicitly state that this was shown only for the first half an hour.

Background:

Considering the lengths of the other paragraphs in this section and the focus of this paper I recommend leaving out the part from p20430, l20 to p20431, l4.

P20431, l9-10: What do you mean with the phrase "the **transient** phase of c-to-c **transition**"? Generally, why is this transition so important? What physical processes are important and which contrail properties are affected? In my opinion the vortex phase is much more important, since you have a large height increase and substantial crystal loss as other studies show (Huebsch Lewellen, 2006; Unterstrasser et al., 2008).

P20432, l23: I suggest to quote some findings of the recent papers on the contrail vortex phase by Huebsch Lewellen and Unterstrasser et al. Especially the first paper shows that some results of the Lewellen Lewellen study are out-dated, since the assumptions in the microphysics module were too strong. Like the present study they used monodisperse crystal size distributions in each grid box which led to an underestimation of the crystal loss.

P20433, l5: The most important parameter is relative humidity since this controls the visibility.

P20436, eq (2): From a microphysical standpoint it is a limitation to not allow the total sublimation of ice crystals. This crystal loss could lower the optical depth of the contrail(-cirrus) (compare your statement in the abstract). Please mention this limitation of your model, as the above mentioned publications put a main focus on specifying the crystal loss. On the other hand, your approach is fortunately justified for the simulations shown in this study. For the selected ambient condition (high supersaturation) the crystal loss is nearly negligible (see Huebsch Lewellen). Contrary to the Lewellen Lewellen study your assumption of monodisperse size distribution in each grid box is reasonable, as long as you do not discuss crystal loss in detail. The ice mass evolution should not be affected too much by this assumption.

P20436, l6-l14: Remove this section including the Eq. (7) and (8). I think it is sufficient to just mention the application of Sonntag's formula.

P20437, l11- 13: I don't understand this sentence. Do you mean "feature" = "goal" or "have to be properly resolved" instead of "are properly resolved"?

P20437, paragraph 2: Is the first simulation V or VD1? The second simulation is D1, I suppose? Can you please add t_0 and t_{end} of each simulation in figure 1. This also helps to clarify this issue.

P20439, l20: Can you please provide the initial ice mass $I = 4/3\, N_i\, \pi\, r_i^3$? What is the corresponding fuel burn?

P20422, l10: Do you allow crystal loss? I am confused.

Sect 3.1: General advices for improving this part:

a) You mention vortex rings. Do they continue to sink or do they stay at the same altitude? Is it possible to determine whether the ice mass still decreases in this part of the primary wake?

b) Is it possible to determine the plume dilution in the vortex phase similar to Figure 12 for the diffusion regime? How does the cross-section (in an axial averaged sense) or the overall volume of the contrail increase?

c) What fractions of crystals are part of the primary and secondary vortex?

d) It would be interesting to quantify the variability of the microphysical properties along the flight axis. Could you show vertical profiles of ice crystal number and mass for several x-values (more than 2 samples as done in figure 7)? Can you include a position in x where a vortex ring occurs? Does the variability increase or decrease with time? Can you show data from both sub-simulations?

e) Figure 8: I am not sure about the interpretation of this figure. Does the volume over which ice with 2e-6 kg/m3 is spread increase with time, as the left panel indicates? Does this imply the ice mass still decreases in the core region between 240 and 320s? Regarding the right panel is it really possible that the crystal sizes range from 0.5 to 20um for a **fixed** ice mass concentration of 1e-5kg/m3. This corresponds to large range of number concentrations, approximately of order $(20/0.5)^3$. This also implies that the values of r on the ρ_i-isosurface depend on N_i and the dilution over time. And it is not directly related to deposition growth?

f) Figure 9: It would be interesting to see how the distributions change if you started with a non-monodisperse distribution.

P20443, l1: Q_{ext}=2 is not only the middle of the mentioned range, it has a physical meaning: It is the geometric optics limit for large size parameters (=$2\pi r/\lambda$) with r particle radius and λ wavelength)

P20443, l2: Sussmann Gierens show lidar, not satellite data.

P20444, Eq (20) - (23): Please specify u'_{th}, u'_1, u_f more precisely. I can only guess the meaning of the formulas.

P20445, l9-l12: I think especially the formulation of the first part of the sentence can be improved.

Figures

Figure 1: Why is the potential temperature not constant around the vortices along the y-direction at t=0?

Figure 8: Can you enlarge the figure by rotating it by 90° ? Also use a single color bar.

Figure 13 and 14: Can you combine them to 3x3 panel?

Figure 14, lower row: What is the reason for the small dark red dots in the middle and right plot? Is it a numerical artefact or how can these odd singularities be physically explained?

Typographical errors and language topics:

20433, l21: Remove "to" in the first sentence

P20434, l24/25: replace "tested in the simulations" by "tested with/by simulations"

P20439, l19: replace legnth by length

P20440, l17:counter-rating ; l21: verfied

P20441, l7: replace "break up" by "break-up" to be consistent.

P20442 Eq (18): it should be dL instead dL_c, as L_c is used as as upper limit $L = L_c$

P20444, l6: legnth

P20444, l8: remove "the"

P20446, l20: tubulent

P20446, l22: almosy

P20447, l6: "transition from ..to .." instead of "transition between .. and .." ??

Figure11, caption: It should be "fed" instead of "feeded"?

Figure 12: Is $D_h = D_y$?

Figure 13, caption: horizonatl

Figure 14, caption: "D_{ref} simulation" = "D1 simulation" ??

References:

Huebsch and Lewellen: Sensitivity Study on Contrail Evolution, 36th AIAA Fluid Dynamics Conference and Exhibit, AIAA 2006-3749, 2006.

Unterstrasser, Gierens and Spichtinger: The evolution of contrail microphysics in the vortex phase, Meteorologische Zeitschrift, 17, 145-156, 2008.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 20429, 2009.