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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Large-eddy simulations of contrails in a turbulent atmosphere" *by* J. Picot et al.

Anonymous Referee #1

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Overview

The paper presents and discusses six LES simulations of young contrails. In particular, the effect of turbulence is investigated by employing sophisticated model developments. I appreciate the efforts of the authors to improve the turbulence representation in their model and analyze the turbulence effect on contrails with high fidelity. In general, the work is suited to be published in ACP, yet only after several corrections/additions have been included. The relevance of turbulence compared to other environmental conditions should be made clearer.

My impression is that some explanations/descriptions are more complicated than

necessary. The explanations should be more straightforward in several places in order to help the reader.

Most of the analysis focuses on wake vortices, not so much on the contrails. The discussion in Section 4.1 is self-contained and the selection of most of the included figures appears sensible. Nevertheless, wouldn't it be more illustrative to show vertical profiles of contrail mass/number rather than some λ_2-based properties as done in Figure 8?

Your introduction mentions recent works by Lewellen et al. (2014) and Unterstrasser (2014). These studies and also Naiman et al. (2011) attempt to explore a large parameter space as contrail evolution depends on many environmental and aircraft parameters. I understand that your focus is a different one, namely towards development of a more sophisticated turbulence representation. Your results suggest a weak impact of turbulence, which could not be known in advance and thus does not invalidate your efforts and results. Nevertheless, I would appreciate when further simulations are carried out to explore the sensitivity of more significant parameters. This should not be postponed to future studies. Including the Kelvin effect would also allow to compare your simulations better with other recent studies.

Major comments

I propose several (major) additions that can make the paper's results stronger.

- Lewellen et al. (2014, p.4404) and Lewellen (2014, p.4436) state that contrail properties depend not only on statistical properties of the turbulent fields, but also on the specific realization of the turbulence field. Are your reported differences between cases 1-3 significant, especially as they are sometimes small? Figure 2 nicely shows the boxes from where you extracted your specific flow field. I

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recommend to shift the boxes to other positions (one or two extra simulations). In the present selection, the values in the right panel are mostly negative (bluish). What would happen if you selected a box from a reddish part of the domain? Anyway, how do you manage to have periodic boundary conditions in the end?

- Stratification strongly affects the wake vortex decay. What about testing a second value of N?
- Your value of EI_s is at the lower end of the range investigated by Lewellen (2014, see their Fig. 2). The lower EI_s is, the fewer ice crystals get lost. In addition to the omission of the Kelvin effect, this could explain your high survival rates compared to other studies. The present study would benefit from a EI_s-variation.
- p29509: Unlike all other recent simulations studies you did not consider the Kelvin effect, although it was shown to affect contrail microphysics. I strongly recommend to include the Kelvin correction term in the deposition equation. See, e.g., Eq. 14 in Naiman et al. (2011). This should not be postponed to a follow-up study as proposed in Sect. 5. Moreover, the inclusion of the Kelvin effect would make comparisons between the various modeling studies more conclusive and improve your Sect. 5.

Minor comments

- Your flow field analyzes suggest vortex break up after two minutes. For case 4, most of the ice crystals get lost after that time. I always thought that the vortex sinking is the main driver for crystal loss. What is the reason for the continued ice crystal loss? As mentioned above, vertical profiles of, e.g., contrail ice mass may reveal vortex sinking for a longer time.

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- Figure 1: I think it is not necessary to include Figure 1. In my opinion it would be enough to add one sentence in the text and simply report the dimensions of the domain that has the highest resolution, i.e. 1m x 1m x 4m.
- Figure 9: The three selected cases look fairly similar. In my opinion, it is enough to show just one case or replace two of them by cases 4 or 5.
- Quantity L_x (length of vortex axis): I understand that L_x helps to identify the time of vortex collision. However, the description of how L_x evolves seems longer than necessary to understand the contrail evolution.
- Is it necessary to define the H_p^{act}, as done in Eq. 5? In p29511, l.12, you state that the particle are activated anyway. Your simulations start at a wake age where nucleation has long been finished. So would it not be better to not speak of nucleation sites? And instead just say "ice crystals". Or do I mix up anything?
- LPT method:
  - Are 2 million particles enough? Naiman et al. (2011) speculate that 8 millions particles might be not enough? Unterstrasser (2014) states that the number of simulation particles is not a limiting factor, however they use more particles than you do.
  - The relevant turbulence, does it happen on the resolved scales, or on the subgrid scale? Is subgrid scale motion considered for ice particle transport? Is it important?
- The comparison with observations is neither very conclusive nor convincing. The environmental and aircraft parameters in your simulations and the observations are not similar or unspecified. What do you want to demonstrate with these comparisons? Are your interpretations and drawn conclusions robust? Naiman et al. (2011, Section 5) shows a profound attempt to compare simulations results

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with observations. However, I am not sure, whether such an exercise has to be reproduced here.

Technical comments

- Table 3, column "Fraction ..": Is the last digit of the given numbers significant?
- There are often parentheses around references that should not be there?
- What does "complete mixing" mean?
- p29516, l.18: Is $M_i = M_{v,0}$ true per definition or by chance? The formulation is not clear.
- Abstract, l. 17: "However" would be more appropriate than "on the other hand".
- Typos:
  - Caption of Figure 14: aircrafty
  - Abstract, l.16: remove "be"
  - p29504, l.3: Kolmorogov
  - p29506, l.10: EI_s value correct?
  - p29518, l.22: I do not understand the definition of S_{xy}.

References

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Naiman, A. D., Lele, S. K., and Jacobsen, M. Z.: Large eddy simulations of contrail development: Sensitivity to initial and ambient conditions over first twenty minutes, J. Geophys. Res., 116, D21 208, doi:10.1029/2011JD015806, 2011.

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