Project: **832**

Project title: **Cloud-resolving modeling of contrails and cirrus**

Principal investigator: **Simon Unterstrasser**

Report period: **2022-11-01 to 2023-10-31**

INTRODUCTION

We employ the LES model EULAG-LCM for simulations of naturally forming cirrus and for aircraft induced cirrus, so-called contrail-cirrus. The microphysical module LCM uses Lagrangian particles to transport the ice crystals and calculate the microphysical processes along their trajectories (Sölch & Kärcher, 2010). The simulations can be grouped into three categories: Simulations of contrail formation (first few seconds), young contrails (age < 5min) and simulations of contrail-cirrus and natural cirrus (time scale of hours).

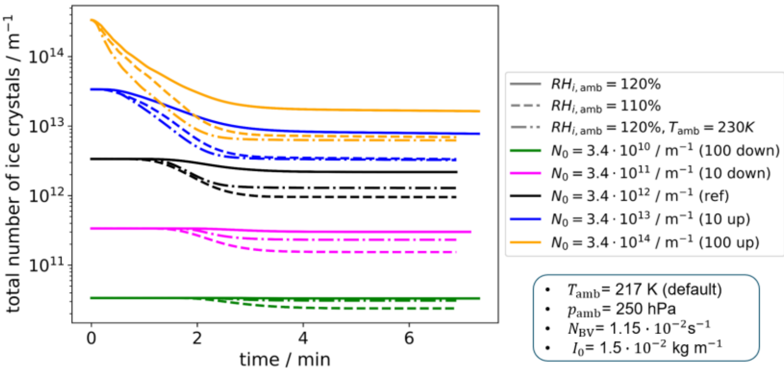
Six researchers belong to project 832 and the group size has grown a lot recently.

MIGRATION

After migrating to Levante, several simulation setups that haven't been tested in 2022 produced errors. Extensive testing was needed that consumed non-negligible resources.

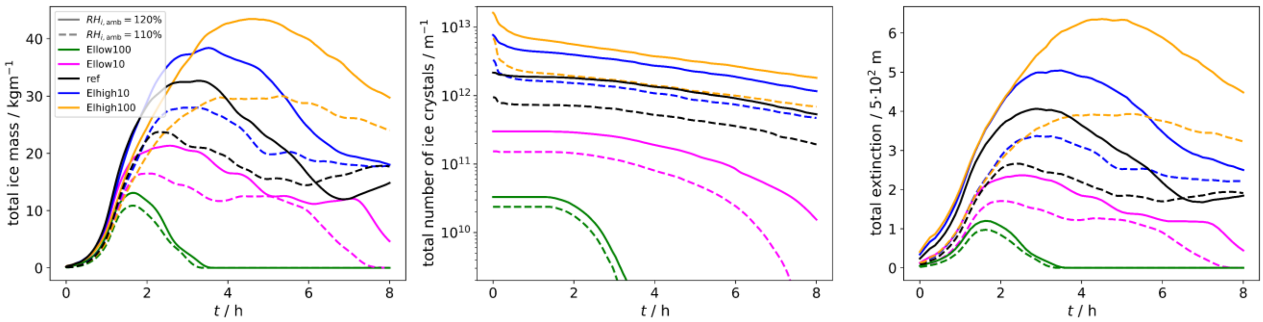
H$_2$CONTRAIL-VP

The block called "H2CONTRAIL-VP" deals with high-resolution simulations of young contrails during the vortex phase (VP) that is characterised by an interplay of ice microphysics and wake vortex dynamics. For typical kerosene combustion, contrail ice crystals form on emitted soot particles (Bier et al, 2022). Hydrogen combustion is a promising technological mitigation option of the aviation's climate impact. When burning hydrogen (H2), no soot particles are emitted and fewer ice crystals form on entrained ambient aerosol particles (Bier et al, in review). Figure 1 shows the temporal evolution of the ice crystal number of the first few minutes of the contrail life time for different initial ice crystal numbers (factor 10 and 100 up/down relative to a typical "kerosene" contrail, different colours). Moreover, various atmospheric scenarios have been analysed, where the ambient temperature and relative humidity have been varied[1].



H$_2$CONTRAIL-DP

The block called "H2CONTRAIL-DP" deals with high-resolution dispersion phase (DP) simulations of aging contrail-cirrus. With such simulations, changes in climate-relevant contrail-cirrus properties are evaluated and its dependence on the initial ice crystal number is explored. Figure 2 shows the temporal evolution of the total contrail ice crystal mass, number and extinction. This depicts the evolution for one idealised synoptic scenario. Simulations are typically performed for a representative set of synoptic scenarios, which are prescribed in the LES model.



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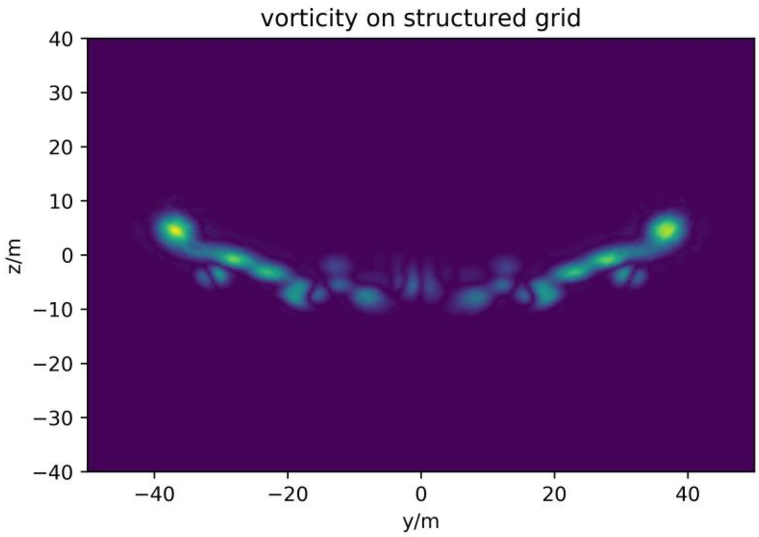
[1] N_0: initial number of ice crystals, I_0: amount of emitted water vapour, N_{BV}: Brunt Väisälä frequency, $RH_{i,amb}$: relative humidity with respect to ice

GEESE

In our last year's proposal, we mentioned the project proposal GEESE. It has been elected for funding and the EU project GEESE started in July 2023. In this project, we will improve and extend the contrail simulation setup for contrails behind aircraft formations. First simulations of the contrail vortex phase with an improved initialisation of the wake vortex flow field have been performed and will be performed in the upcoming months. Figure 3 shows such an initial flow field for our EULAG-LCM simulations. The data are obtained from a RANS model that simulates the flow around the full aircraft geometry. The vorticity patterns show nicely the aircraft geometry (body + wing) and the strong localised vorticity in the wing-tip vortices (at the outer edges).



H_2CONTRAIL-FC

This activity is about the contrail evolution behind TurboProp aircraft with H2 fuel cells and hasn't started yet. This block will appear in this year's proposal again.

SUMMARY

Our estimate of project resources was too conservative in last year's proposal and we could do more simulations than our budget allows. Hence, the proposal this year will ask for more computing time.

REFERENCES (the team members are in bold font):

- **Bier, A., S. Unterstrasser**, and X. Vancassel: Box model trajectory studies of contrail formation using a particle-based cloud microphysics scheme, *ACP, 2022, 22(2), pp. 823–845, https://acp.copernicus.org/articles/22/823/2022/acp-22-823-2022.html*

- **Bier, A., Unterstrasser, S., Zink, J., Hillenbrand, D.,** Jurkat-Witschas, T., and **Lottermoser, A.:** Contrail formation on ambient aerosol particles for aircraft with hydrogen combustion: A box model trajectory study, EGUsphere [preprint], in review, https://doi.org/10.5194/egusphere-2023-1321, 2023.