Project: **832**
Project title: **Cloud-resolving modeling of contrails and cirrus**
Project lead: **Simon Unterstrasser**
Report period: **2016-01-01 to 2016-12-31**

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 paths (Sölch & Kärcher, 2010). The simulations can be grouped into two categories: Simulations of young contrails (age < 5min) and simulations of contrail-cirrus and natural cirrus.

Young contrails

Many simulations of young contrails and their interaction with the aircraft-induced wake vortices have been performed within this project in the former years. See publications Unterstrasser et al, 2014, Unterstrasser 2014 and Unterstrasser & Görsch, 2014.

All of the above mentioned simulations as a whole represent a large database of early contrail evolutions which helped to gain fundamental and detailed process understanding. A last publication summarizing all simulation results in way that the most important findings can be incorporated in a GCM has been submitted at the end of the year 2015. During the review process no further simulations were asked by the reviewers. Hence, no vortex phase simulations have been carried out in the reporting phase. The publication "*Properties of young contrails – a parametrisation based on large-eddy simulations*" appeared as an ACP-paper in 2016.

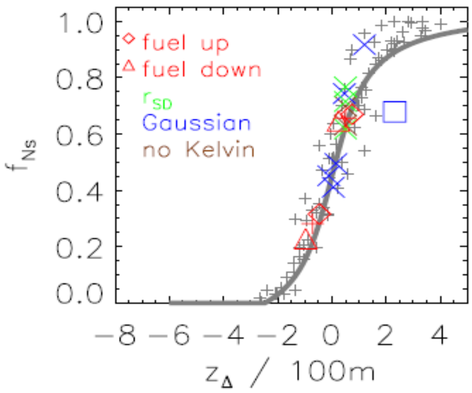


Figure 1 is taken from this publication. On the y-axis the fraction f_{Ns} of surviving ice crystals is shown (this is a relevant property of young contrails). Each data point shows the result of a 3D simulation for specific atmospheric background and aircraft properties. By introducing the variable z_Δ, the simulations results can be approximated by the grey line. Hence, we found a simple description for the properties of young contrails despite being governed by complex dynamical and microphysical processes. The parametrization is suited to be incorporated in contrail parametrizations in global climate models, where it can replace the rather crude initialisations used so far. This will allow for more robust climate-related estimates, e.g. how biofuels alter the contrail radiative forcing.

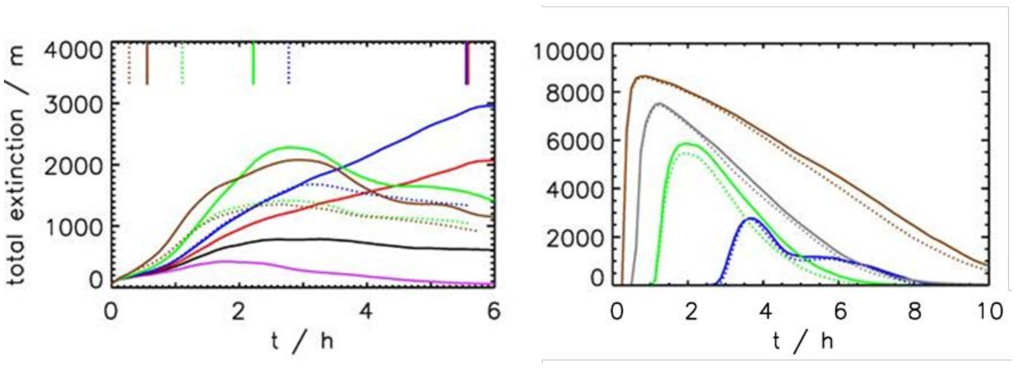
Moreover, simulations of young contrails generated by a new generation blended wing body aircraft had been performed some time ago and now contribute to a climate assessment study of this new aircraft design (Grewe et al, 2016).

Contrail-cirrus simulations and natural cirrus simulations

Generally, we use the output of vortex phase simulations (contrails after 5 minutes) to initialise contrail-cirrus simulations which cover the remaining life cycle of a contrail. We've been continuously performing simulations of contrail-cirrus and natural cirrus with various questions in mind. In the meantime, two companion manuscripts have been submitted and accepted.

In a first step we did separate simulations of either contrail-cirrus or natural cirrus. This helped a lot to quantify how different the two cloud types are and whether it is likely that both cloud types can be distinguished in observations. This includes analyses of their microphysical, geometric, thermodynamic and optical properties and helps to interpret in-situ measurements of cirrus (as taken during the large HALO campaign ML-Cirrus), where it is a priori not clear, whether contrail-cirrus or natural cirrus or a mix of both is sampled. The title of the first paper is "*Numerical simulations of homogeneously nucleated natural cirrus and contrail-cirrus. Part 1: How different are they?*".

The next figure shows the total extinction of contrail-cirrus on the left and of natural cirrus on the right for various synoptic scenarios (variation of updraught speed or cooling rate, resp.). Total extinction serves as a metric for the radiative significance of an ice cloud. Weak, but enduring updraughts allow for the longest life times of contrail-cirrus (red and blue curve). For cirrus clouds, the updraught speed during their formation is most crucial and strong updraughts lead to the longest-living clouds (see brown curve).



In a second step, we performed simulations of contrails that become surrounded by natural cirrus. In this case, the contrail spreading is inhibited and both cloud types compete for the available water vapour. In observations it is difficult to track contrail-cirrus once it lost its line shape and becomes similar to natural cirrus. Our simulations address questions such as “how long can you expect to be able to distinguish a contrail from the surrounding natural cirrus. The title of the second paper is “*Numerical simulations of homogeneously nucleated natural cirrus and contrail-cirrus. Part 2: Interaction on local scale*”.

Only very few additional simulations had to be carried out during the review stage of the two manuscripts.

Conclusion

In 2016, the focus of my work was to publish simulation results. During the review process, only few additional simulations were performed. Due to the small team size of the project, no other scientist performed simulations within this project. Hence, in total much fewer computing resources were demanded than anticipated.

References

Grewe,… , Unterstrasser, ..: *Assessing the climate impact of the AHEAD multi-fuel blended wing body,* Meteorol. Z. ., accepted

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