Project: **832**

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

Principal investigator: **Simon Unterstrasser**

Report period: **2019-01-01 to 2019-12-31**

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 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).

The BMBF-project "FORMIC" project deals with the potential climate benefits of formation flight and will end in 2019. During a formation flight, several aircraft fly in a pattern similar to that of migrating birds. Fuel usage and CO2-emissions are reduced compared to isolated flights due to aerodynamic benefits of this special flight pattern. Besides this fuel effect, the climate impact of contrails may be strongly altered, as several contrails start to overlap and interact already at a very early stage of their lifetime. This saturation effect was shown to reduce the contrail radiative forcing (RF), i.e the RF of one contrail cluster formed by two aircraft flying in a formation is smaller than that of two isolated contrails. Within this project simulations of young contrails and contrail-cirrus are performed.

Moreover, a DFG-funded project on contrail formation started in March 2019. It deals with high-resolution 3D simulations of contrail formation in the expanding exhaust jets. In the past, contrail formation was either studied with box models (with detailed microphysics, but simplified dynamics) or with 3D LES models (detailed dynamics, but simplified microphysics). The current project aims at bringing those two worlds together and extending EULAG-LCM such that high-resolution 3D simulations of contrail formation with adequate dynamics and microphysics can be performed.

Short summary

So far only small test simulations have been performed this year and the project's consumption is less than anticipated in last year's proposal. Unfortunately, this can happen in small teams. Currently, we are two investigators in this project; me (currently on parental leave) and Andreas Bier who joined a few months ago.

Simulation block "DFG-JP"

As written in the last year's proposal, EULAG-LCM has to be extended in several ways for contrail formation simulations. Since March 2019, the "special" microphysics of ice crystal formation in contrails was in included in the box model version of LCM. Currently, those modifications are implemented in the full LCM that is coupled to EULAG and Andreas Bier just started to run test simulations at DKRZ. This work will continue over the rest of the year.

Simulation block "FORMIC-VP"

A manuscript describing the results of FORMIC-VP simulations (as described in previous proposals) was submitted to the high-profile journal "Physics of Fluids", where it was rejected as out-of-scope. Currently, the manuscript is in review in "The Aeronautical Journal" and it may still happen that the review process requires carrying out additional simulations (as described in last year's proposal).

Simulation block "FORMIC-DP"

Due to other commitments, it was not possible to carry out further contrail-cirrus simulations of formation flight scenarios. This activity will be resumed once a publication on this topic is prepared (probably in mid-2020)

References

Sölch, I. and Kärcher, B, 2010.: *A large-eddy model for cirrus clouds with explicit aerosol and ice microphysics and Lagrangian ice particle tracking*, Q. J. R. Meteorolog. Soc., 136, 2074–2093

Unterstrasser, S. and Stephan, A.: *Far field wake vortex evolution of two aircraft formation flight scenarios and implications on young contrails*, in review in “The Aeronautical Journal”