Project: **832**

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

Principal investigator: **Simon Unterstrasser**

Report period: **2021-11-01 to 2022-10-31**

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).

The group of researchers who belong to project 832 has grown a lot recently, from 2 to 6 members.

The **expressions** in bold refer to simulation blocks in last year's proposal.

ConForm

The DFG-funded project of A. Bier (*b309062*) on contrail formation started in March 2019. It deals with high-resolution 3D simulations of contrail formation in 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. Recently, the LCM microphysical model has been extended regarding the contrail microphysics and the publication by Bier et al (2022) reports on box model simulations with the extended LCM. The master's thesis by A. Salah *b309212* (submitted in June 2022) focused on the high-resolution simulation of expanding exhaust jets. In this first step, contrail ice microphysics was neglected and the student investigated dynamical aspects. The simulations have been performed on Mistral. They belong to the block "**DFG-JP"** and could answer several questions raised in last year's proposal.

H_2CONTRAIL

The DLR-internally funded research group deals with contrails effects of hydrogen-driven aircraft. A. Bier worked as a Post-Doc in this project and investigates contrail formation from a propulsion system with direct combustion of H2. Currently, he performs box model simulations, which do not require HPC resources and works on a publication. Three new PhD students have started in our group during the reporting period. However, they all started to work with lower-dimensional models. Full 2D and 3D simulations, which require HPC resources, will follow. The topic described under "**H_2CONTRAIL-VP"** has not yet been addressed.

General code improvements

The state-of-the-art ice microphysical code LCM is coupled to a fairly old version of the LES model EULAG. Lately, we work on coupling LCM to the newest version of EULAG in addition to the migration to Levante. We still face some issues with running the newest EULAG-LCM version properly on Levante. Hence the resource consumption on Levante is not very high so far. These simulations belong to "**MIGRATION**".

Short summary

The majority of simulations during the reporting period had been performed on Mistral and we used up more than two thirds of the granted Mistral computing time. Our model system is not yet fully operational on Levante, and the project's consumption on Levante will likely be less than anticipated in last year's proposal.

Publications (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*

- **A. Salah**: High Resolution Simulations of Turbulent Jet Expansion with EULAG-LES, master's thesis TU Munich, Computational Science and Engineering (International Master's Program), Submission date: June 1st 2022