Project: **832**
Project title: **Cloud-resolving modeling of contrails and cirrus**
Project lead: **Simon Unterstrasser**
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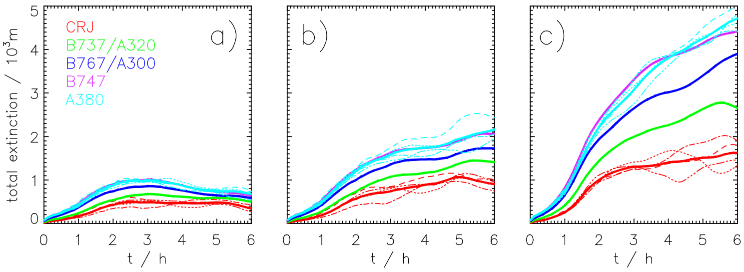
We employed the LES model EULAG-LCM for simulations of naturally forming cirrus and for aircraft induced cirrus, so-called contrail-cirrus. The microphysical module LCM uses Lagrangian particles to transport the ice crystals and calculate the microphysical processes along their paths (Sölch & Kärcher, 2010). The simulations can be grouped into two categories: Simulations of young contrails (age < 5min) and simulations of contrail-cirrus and natural cirrus. We label the simulations as in the request form 2013.

VORTEX_1 and AIRCRAFT:

We performed simulations of young contrails for 6 different aircraft types. Contrail-cirrus simulations have shown that aircraft type has a long-lasting impact on the properties of the evolving contrail-cirrus. In the meantime, the results have been published in Unterstrasser & Görsch, 2014, JGR. The figure shows the long-term evolution of the contrail total extinction (which is basically a measure of the total shortwave radiative effect).

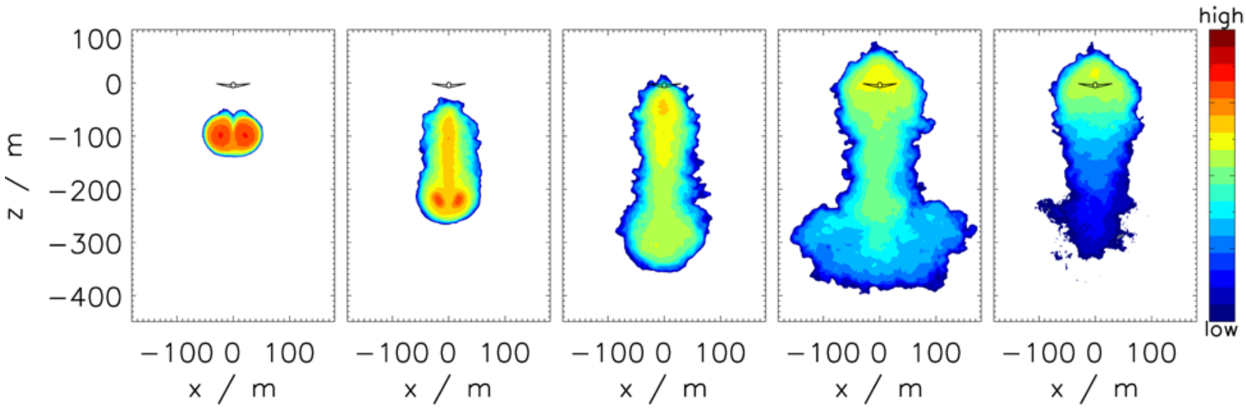


Moreover, an observational contrail study which was accompanied by EULAG-LCM simulations appeared in Jeßberger et al, 2013 (not yet published at the time of the last report).

VORTEX_2:

Prior to the vortex_1-simulations, simulations for a fixed aircraft type were performed.

In a first step, the dilution of a passive tracer in the wake vortex behind an aircraft was evaluated for many atmospheric parameters. The results have been published in Unterstrasser et al, 2014, ACP. In a second step, the focus was on contrail evolution and variation of the microphysically relevant parameters. In the meantime, the results have been published in Unterstrasser, 2014, JGR. The figure shows cross-sections (perpendicular to the flight direction) of ice crystal number



concentrations in a 1, 2, 3, and 5 minute old contrail for relative humidity RH_i=120%. The right most panel shows a 5 minute old contrail for RH_i =110%.

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. Based on them, I devised an analytical parametrisation of contrail properties (after 5 minutes). This work will soon appear in ACPD. The great advantage of this parametrisation is that more realistic contrail initialisation in GCMs can be developed with it. This will allow for more robust climate-related estimates, e.g. how biofuels alter the contrail radiative forcing.

CLUSTER:

Several types of contrail-cirrus and contrail-cluster simulations have been performed. One set of simulations dealt with the question how similar contrail-cirrus and natural cirrus are. This 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.

Two manuscripts on this are currently under preparation and should be ready to submit by the end of the year.

Moreover, EULAG-LCM reference simulations for a dedicated comparison with CoCip (a simplified, global scale contrail model; Schumann, 2012) have been performed and allowed to rate the performance of the simplified model (Unterstrasser & Graf, 2014).

GMDD-paper:

For the review of the GMDD-paper, some new simulations had to be carried out. In the meantime, the paper has been published. EULAG-LCM simulations rely on a particle based approach for ice microphysical treatment. Contrary to Eulerian approaches, where the cirrus properties are defined on a grid, our Lagrangian approach uses a large number of simulation particles that represent the cirrus. Clearly, the computational effort scales (mostly linearly) with the number of used simulation particles. In the GMD-paper, several techniques are described, that allows a significant reduction of simulation particles and makes the simulations less demanding in terms of computing time and memory space.

Publication based on simulations performed at DKRZ:

published

1. Jeßberger, P., Voigt, C., Schumann, U., Sölch, I., Schlager, H., Kaufmann, S., Petzold, A., Schäuble, D., and Gayet, J.-F.: Aircraft type influence on contrail properties, Atmos. Chem. Phys., 13, 11965 - 11984, 2013.
2. Unterstrasser, S. and Sölch, I.: Optimisation of simulation particle number in a Lagrangian ice microphysical model, Geosci. Model Dev., 7, 695–709, 2014.
3. Unterstrasser, S., Paoli, R., Sölch, I., Kühnlein, C., and Gerz, T.: Dimension of aircraft exhaust plumes at cruise conditions: effect of wake vortices, Atmos. Chem. Phys., 14, 2713–2733, 2014
4. Unterstrasser, S. and N. Görsch: Aircraft-type dependency of contrail evolution, J. Geophys. Res. Atmos.,119, 14015 - 14027, 2014
5. Unterstrasser, S.: Large-eddy simulation study of contrail microphysics and geometry during the vortex phase and consequences on contrail-to-cirrus transition, J. Geophys. Res. Atmos.,119,7537-7555, 2014
6. Unterstrasser: Contrail-cirrus evolution with EULAG-LCM and CoCiP – A comparative study, WeCare-Projekbericht, 17 Seiten, 2014
7. Unterstrassser, S: Properties of young contrails - A parametrisation based on Large Eddy Simulations, ACPD, 2015

To be submitted soon

1. Unterstrasser, S., K. Gierens, Ingo Sölch and Martin Lainer: Comparative numerical study of the evolution of cirrus vs. contrail-cirrus, to be subm. to Meteorl. Z.
2. Unterstrasser, S., K. Gierens, Ingo Sölch: Interaction of natural cirrus and contrail-cirrus on local scale, to be subm. to Meteorl. Z.

Further references:

Schumann, U.: A contrail cirrus prediction model, Geosci. Model Dev., 5, 543–580, 2012

Sölch, I. and Kärcher, B.: 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, 2010