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Numerical simulations of persisting contrails with Lagrangian microphysics

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Introduction

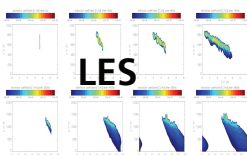
- Estimates of global coverage and radiative forcing of contrail-cirrus still with large uncertainties
- Contrail-cirrus hardly distinguishable from naturally formed cirrus
- Observations of aged (non-linear) contrails virtually not available



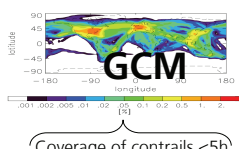
Model-based approach

- Cloud resolving simulations can help to improve the initialization and parameterization of contrails in regional/global scale simulations.

Simulation of contrail life cycle:



Use GCM approach to obtain global contrail-cirrus coverage and radiative forcing:



Burkhardt & Kärcher, 2009

Coverage of contrails <5h

Core model EULAG

- Basic model EULAG solves the anelastic approximation of the Navier-Stokes-equations (including a 1D radiation routine). 2 microphysics modules available.

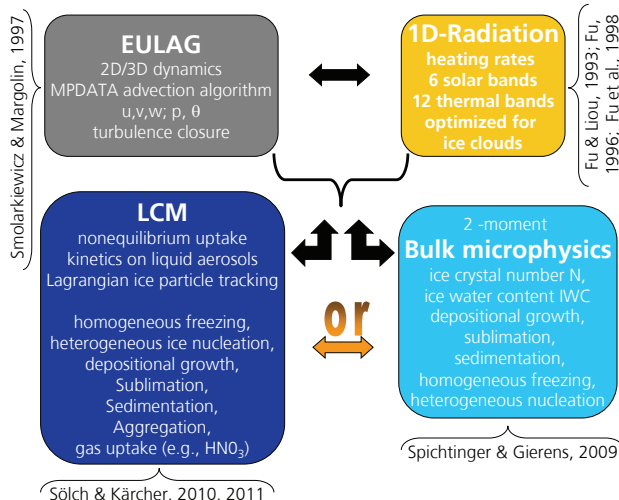
with Bulk ice microphysics (EULAG-BULK)

- 2-moment bulk microphysics routine with assumed lognormal ice crystal size distribution
- Assumed ice crystal shape: hexagonal columns

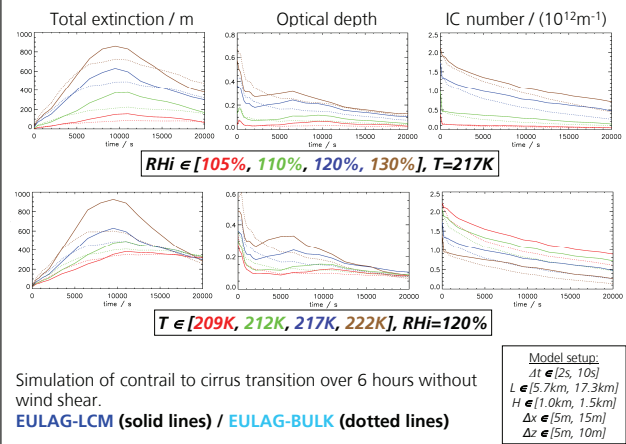
with Lagrangian ice microphysics (EULAG-LCM)

- Lagrangian tracking of ice crystals, crystal size distribution develops freely.
- Microphysical processes solved for individual particles

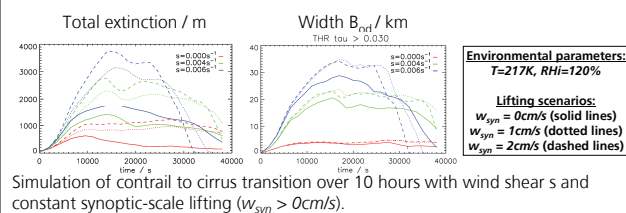
Model overview



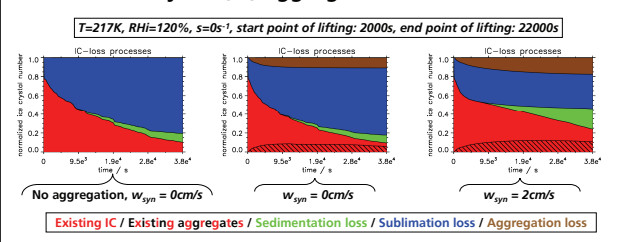
Evolution of contrail (microphysical) properties during the dispersion phase – Comparison



Impact of idealized synoptic scale lifting and vertical wind shear on contrail lifecycle (EULAG-LCM)



Extent of ice crystal (IC) aggregation in a contrail



Selected findings

- Substantial sublimation loss in $w_{syn}=0$ -scenario found in both models. Turbulent fluctuations in RH around saturation cause sublimation (due to Kelvin-effect, Lewellen, 2012).
- Comparison of two microphysical models: Qualitatively similar evolution of contrail properties.
- Total extinction of contrail higher for larger wind shear and stronger uplift. However, reduced lifetime for "bigger" contrails since larger ice crystals fall out faster.
- After 10 hours, only about 11% (18%) of total ice crystals are lost by aggregation if $w_{syn}=0cm/s$ ($2cm/s$). Nevertheless, after 6 hours over 35% (30%) of the present ice crystals are aggregates; after 10 hours 65% (45%).

Acknowledgement

The EULAG-LCM simulations were carried out at the high performance computing facilities of the DKRZ in Hamburg. We want to thank I. Sölch for assistance with the EULAG-LCM model.