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:

**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**

**EULAG**
- 2D/3D dynamics
- IMDATA advection algorithm
- U/V/W, P, 3D turbulence closure
- LCM
- nonequilibrium uptake kinetics on liquid aerosols
- Lagrangian ice particle tracking

- 1D-Radiation
  - heating rates 6 solar bands
  - 12 thermal bands optimized for ice clouds

- 2-moment Bulk microphysics
  - ice crystal number N, ice water content IWC, depositional growth, sublimation, sedimentation, aggregation, gas uptake (e.g., HNO3).

- Simulation of contrail-cirrus coverage and radiative forcing:

**Evolution of contrail (microphysical) properties during the dispersion phase**

**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_s=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_s=0cm/s (2cm/s). Nevertheless, after 6 hours over 35% (30%) of the present ice crystals are aggregates; after 10 hours 65% (45%).

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