Eco-efficient flight trajectories – Using a Lagrangian approach in EMAC to investigate contrail formation in the mid latitudes

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Aviation is seeking for ways to reduce its climate impact caused by CO₂ emissions and non-CO₂ effects. While the effects of CO₂ on climate are independent of location and situation during release, non-CO₂ effects such as contrail formation vary depending on meteorological background.

The ClimOP Project aims to estimate the mitigation potential of climate optimized aircraft trajectories, building on concepts established in previous studies that investigated the influence of different weather situations on aviation’s contribution to climate change, identified climate sensitive regions and generated data products which enable air traffic management (ATM) to plan for climate optimized trajectories [3,4].

In research presented here, a Lagrangian approach is further developed to determine the sensitivity of the atmosphere to aviation transport.

Motivation and Scope

- Contrail-cirrus (57%) are the largest contributors to the effective radiative forcing of global aviation, with large uncertainties in magnitude in part due to incomplete representation of key processes [3].
- A Lagrangian approach can be used to derive 4-dimensional Climate Change Functions (CCFs) [2,4].
- Potential contrail coverage and CCFs are strongly influenced by weather patterns [2].
- Are the essential conditions and processes for the formation and life cycle of contrails realistically represented in the EMAC model? Are adjustments necessary?

Meteorology contrail formation: EMAC vs aircraft observations

Comparing temperature and humidity based on airborne observations (HALO measurement campaign, CARIBIC/IAGOS) and different EMAC model setups.

- Temperature difference between observations and simulation (up to 5 K).
- Strong correlation between model and observational data.

Temperature comparison (EMAC vs. ML-Cirrus observations)

- Probability density function of model and observational temperature data for the ML-Cirrus time period (left). Correlation between observational data and model data (middle). Boxplot for all datasets (right).
- All aircraft observations show a systematic cold bias (for temperature below 235K) and a dry bias (in the troposphere).

Water vapor comparison (EMAC vs. ML-Cirrus observations)

- Probability density function of model and observational humidity data for the ML-Cirrus time period (left). Correlation between observational data and model data (middle). Boxplot for all datasets (right).
- Mixing ratio is similar for dry regions, but differs for humid values between 200 and 400 ppmV.
- Increased correlation for L90 simulation due to reduced output interval (15~12m).
- EMAC shows higher mixing ratio values in the stratosphere compared to obs. data.
- Opposite in the troposphere, improvement with mid temp. nudging.

Lagrangian Approach

- Lagrangian concept to study development and radiative impact of contrails in EMAC/ATTILA.
- Potential contrail coverage (top) and Climate Change Functions (bottom) for different weather situations [2].

Perspectives and Plans:

- Systematic cold bias and dry bias between EMAC and aircraft measurements differs with nudging concept.
- Impact on relative humidity, SSR and potential contrail coverage, adjustments necessary.
- Expand analysis distinguishing different seasons and regions and evaluate existing algorithmic Climate Change Functions (aCCFs) prototypes.
- Novel CCF data will be used to calculate climate optimized flight trajectories within ClimOP project.

References


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