Climate-optimized trajectories FlyATM4E-Solutions

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SESAR 2020 SHOWCASE

Motivation: Aviation climate effects

FlyATM4E

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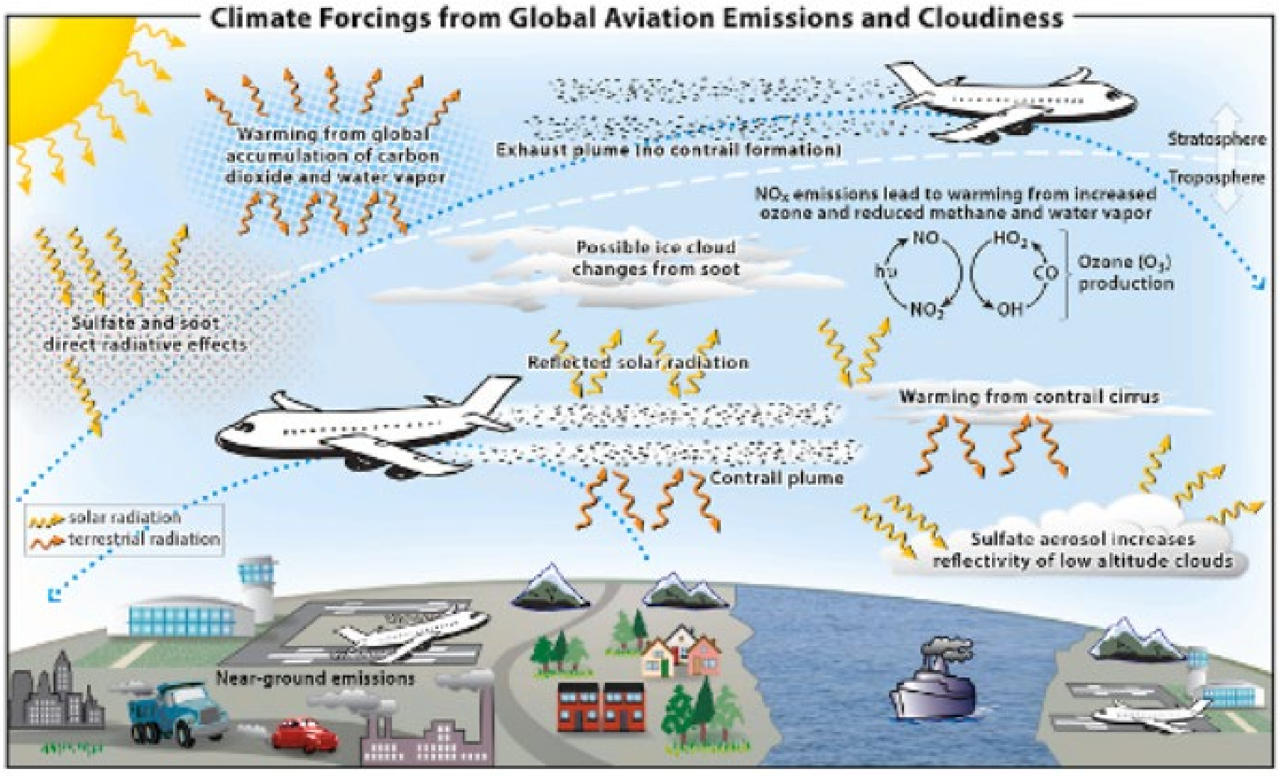

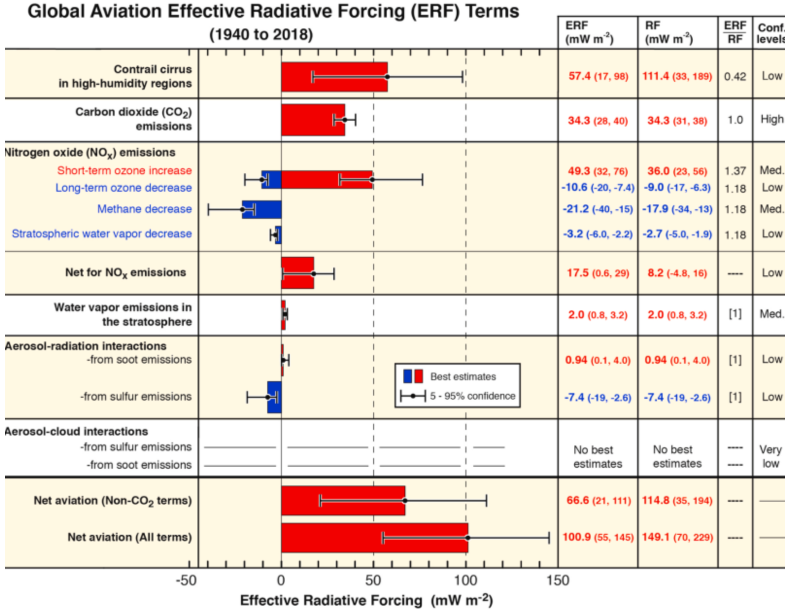

Lee et al. 2021

- **Non-CO_2 effects** are important as they contribute to **total climate effect** of aviation
- Climate effects of non-CO_2 effects **depend on** emission location, meteorological conditions and background concentrations

Overall concept of FlyATM4E

FlyATM4E

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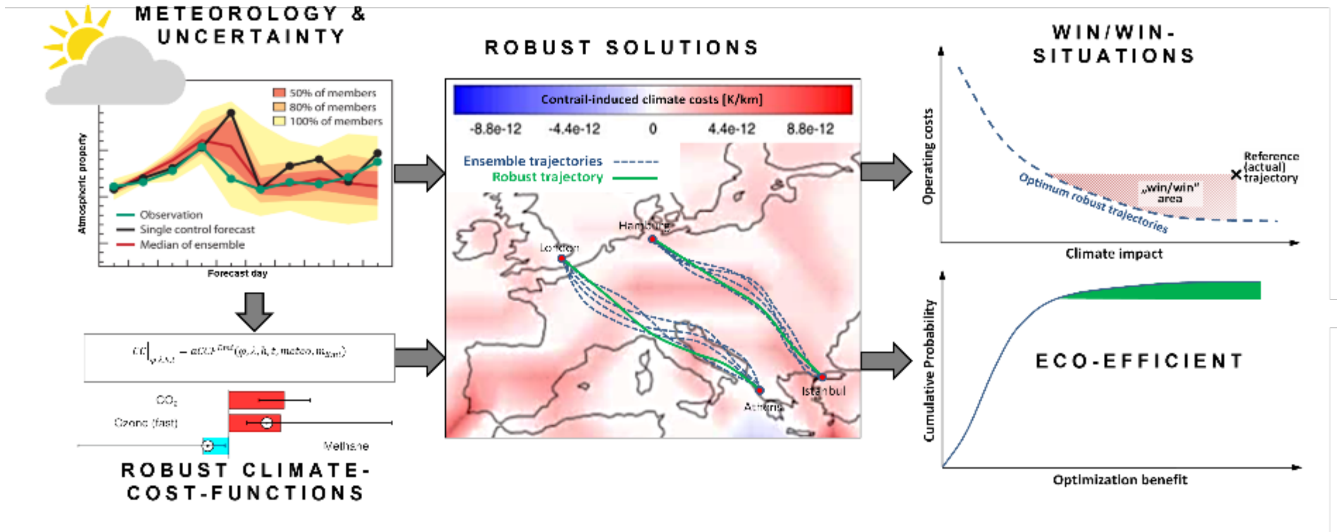

Workflow for
Climate-optimized trajectories
as developed within FlyATM4E

FlyATM4E (Flying Air Traffic Management for the Environment) developed a **concept to identify climate-optimized aircraft trajectories** which enable a robust and eco-efficient **reduction in aviation's climate impact**.

Climate optimized routing takes into account **CO_2 and non-CO_2 climate effects**, such as contrails and contrail-cirrus, water vapour, nitrogen oxide emissions on both ozone and methane and particulate emissions.

Algorithmic Climate Change Functions (aCCFs)

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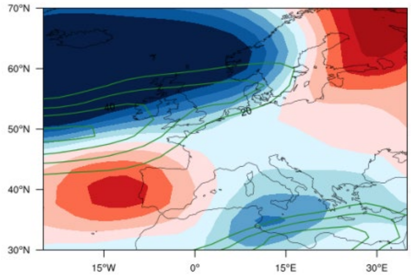
FlyATM4E

- Prototype algorithmic climate change functions (aCCFs) of non-CO_2 effects give **climate impact of aviation emissions at a specific location and time** (in terms of average temperature response ATR).
- aCCFs provided for contrail-cirrus, water vapour, NO_x-induced changes of ozone and methane. First consistent set: **aCCF-V1.0** (Yin et al. 2022, GMDD)
- aCCFs based on meteorological parameters. Can be calculated from e.g. numerical weather prediction data.

METEO, ERA5

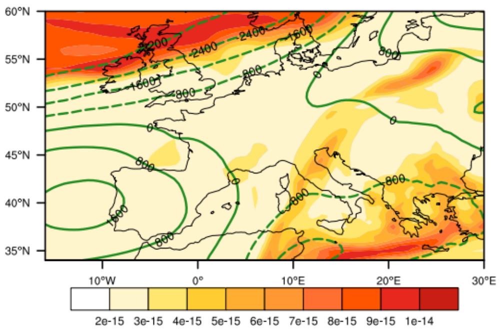
geopotential



aCCFs

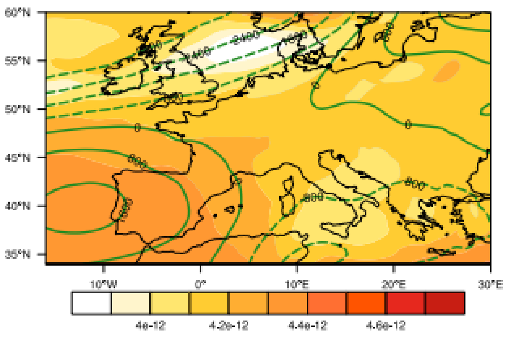
mathematical formulas -> computational efficient

Water vapour aCCF



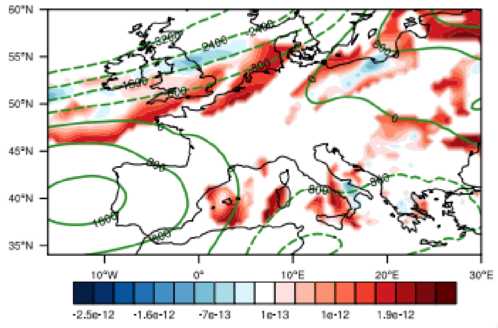
[K/kg(fuel)]

NO_x-induced aCCF



[K/kg(NO2)]

Contrail (daytime) aCCF



[K/km(contrail)]

- Water vapour and NO_x induced aCCF is positive (warming)
- Contrail (daytime) aCCF warming/cooling impact in areas where contrails can form

Candidate Solution: Sol-FlyATM4E-01

Sol-FlyATM4E-01 informs the airspace user on those regions **where aviation emissions have a high climate effect**, while using a physical climate metric in order to provide a spatially and temporally resolved quantitative estimate.

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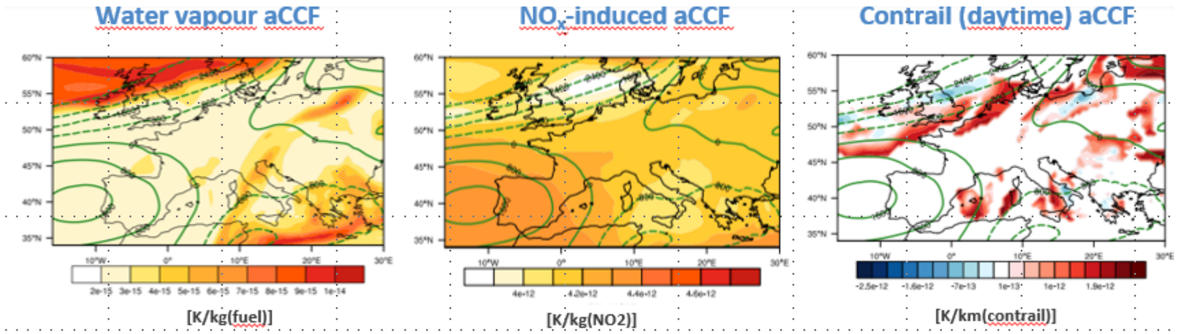
FlyATM4E



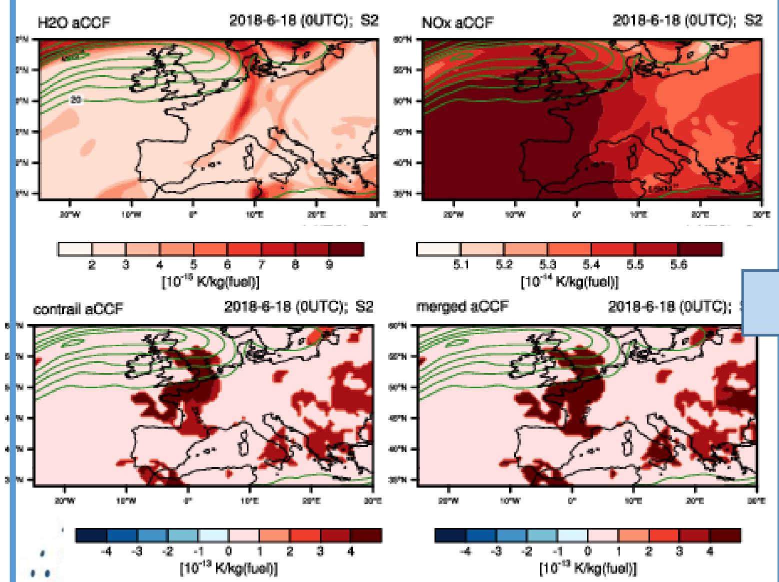
- **advanced MET service** to inform on the climate effect of flight operations comprising CO_2 and non-CO_2 effects
- **spatially and temporally resolved quantitative information on climate effects of aviation emissions** in the airspace -> assess climate effects of aircraft operations.
- Efficient integration (in ATM) relies on **combining aCCFs with numerical weather prediction data & specific aircraft emissions**

Candidate Solution Sol-FlyATM4E-02

Sol-FlyATM4E-02 identifies those aircraft trajectories with lower climate effects by a **trajectory optimisation expanded with an environmental component** relying on Sol-FlyATM4E-01.

Case Study: 18th June 2018 0UTC

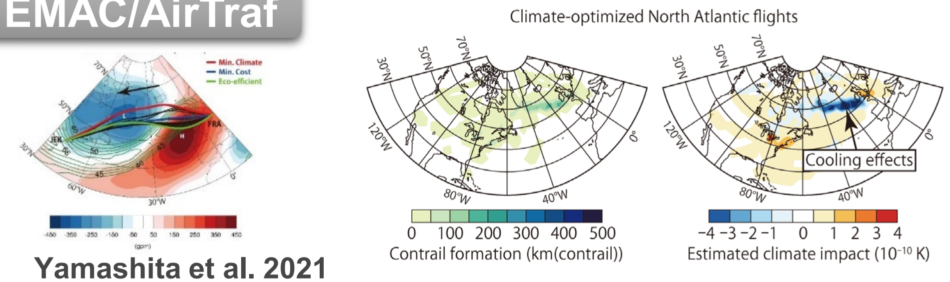
aCCFs



Dietmüller et al. 2022
Matthes et al. 2023 (in prep.)

Aircraft Trajectory Optimization

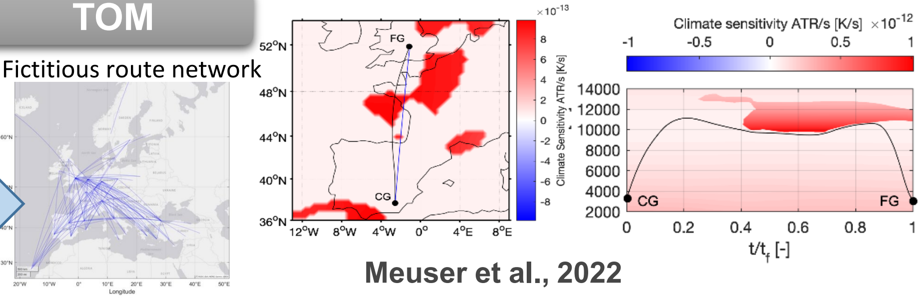
EMAC/AirTraf



Yamashita et al. 2021

TOM

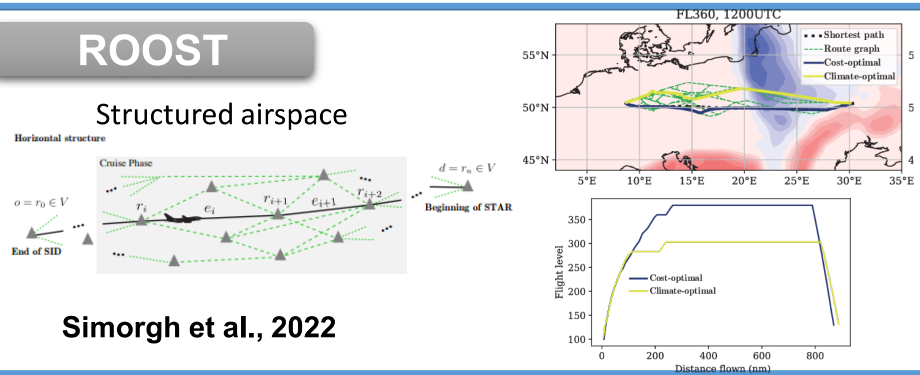
Fictitious route network



Meuser et al., 2022

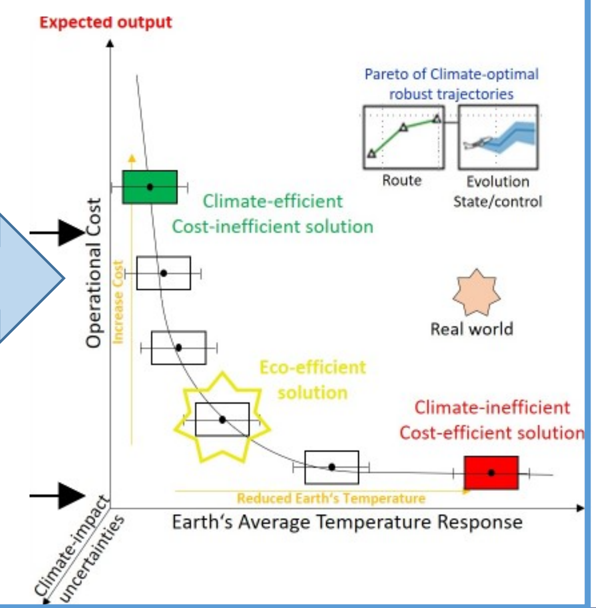
ROOST

Structured airspace

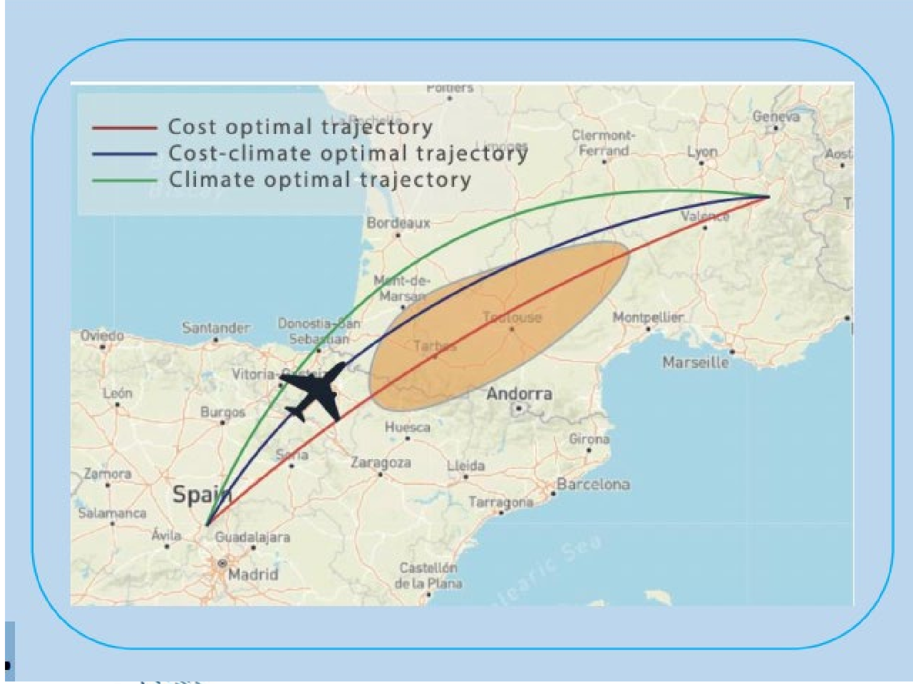


Simorgh et al., 2022

Paretofront



Towards implementation of climate-optimized flight planning



- Having available **a MET-service** in trajectory planning is a prerequisite for **climate-optimized alternative aircraft trajectories** in flight dispatching and network management.
- advanced MET service to **inform on the climate effect of flight operations** comprising CO_2 and non-CO_2 effects
- **Characterization of uncertainties** enables estimation of confidence intervals **in a risk analysis.**
- **Definition of environmental performance indicators requires a dialogue with policy makers and regulators.**