SCENARIO ASSESSMENTS, MITIGATION OPTIONS AND NON-CO_2 EFFECTS IN REGULATIONS

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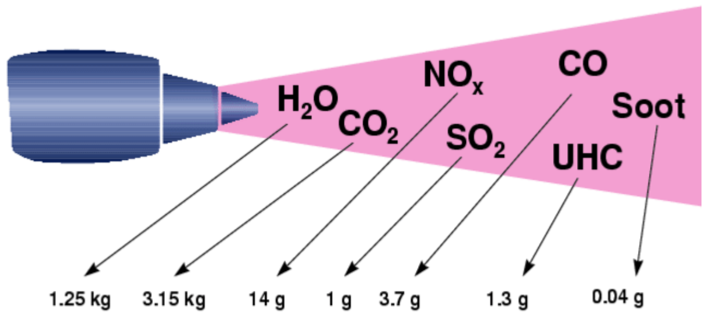
Climate Effects of Aviation Emissions

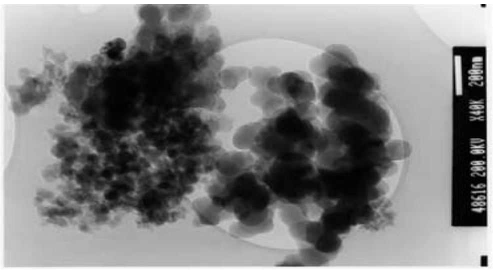
IPCC (1999)



Direct greenhouse gases
CO_2 and H_2O

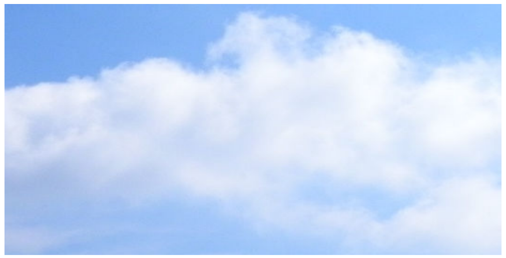
Indirect greenhouse gas chemistry:
NO_x
⇓
Ozone and Methane

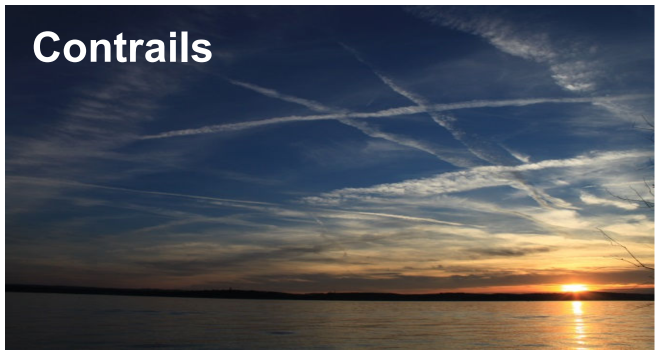
Direct aerosol effect



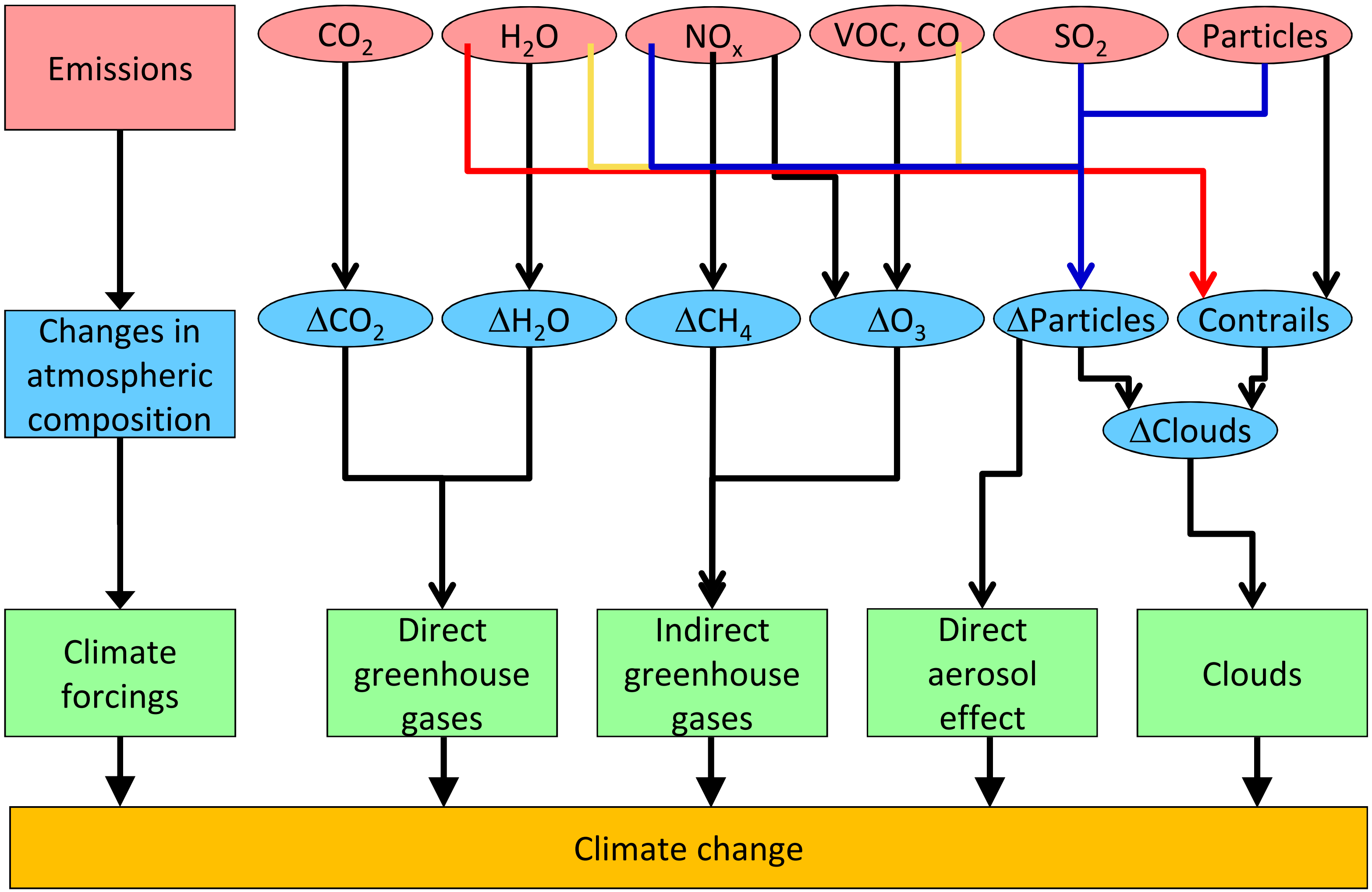
Popovicheva et al. (2004)

Aerosol effects on clouds





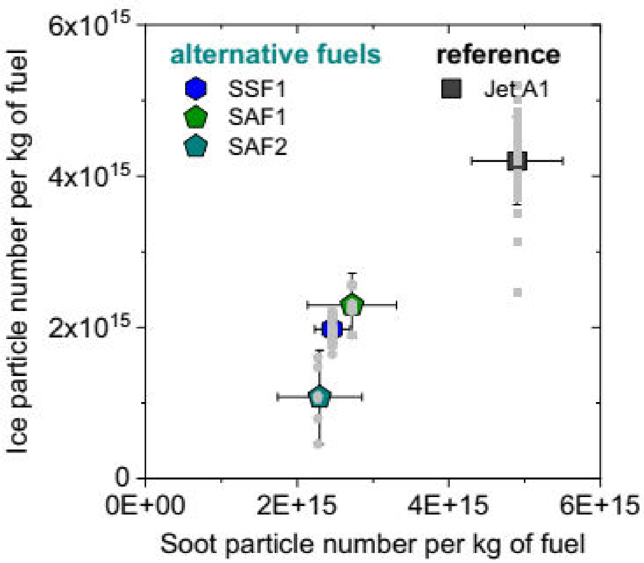
Atmospheric effects of aviation

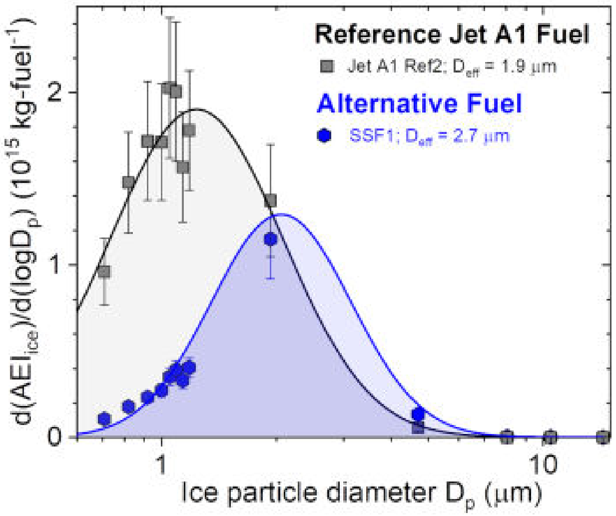


Sustainable Alternative Fuels (SAF)

ECLIF/ND-MAX Measurement Campaign

Reduction in number of soot particles and ice particles by 50-70%





SAF:
Less CO_2
Less Contrail
Climate
Impacts

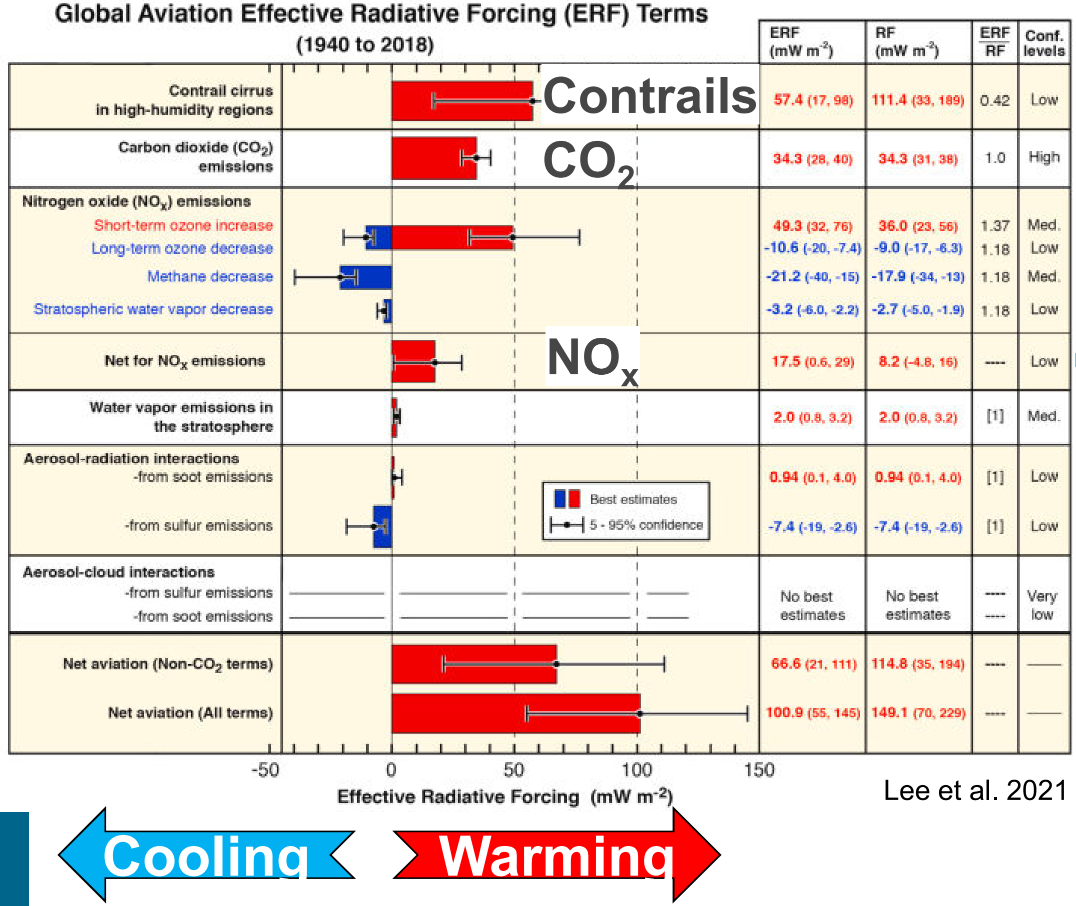
Less and larger ice particles

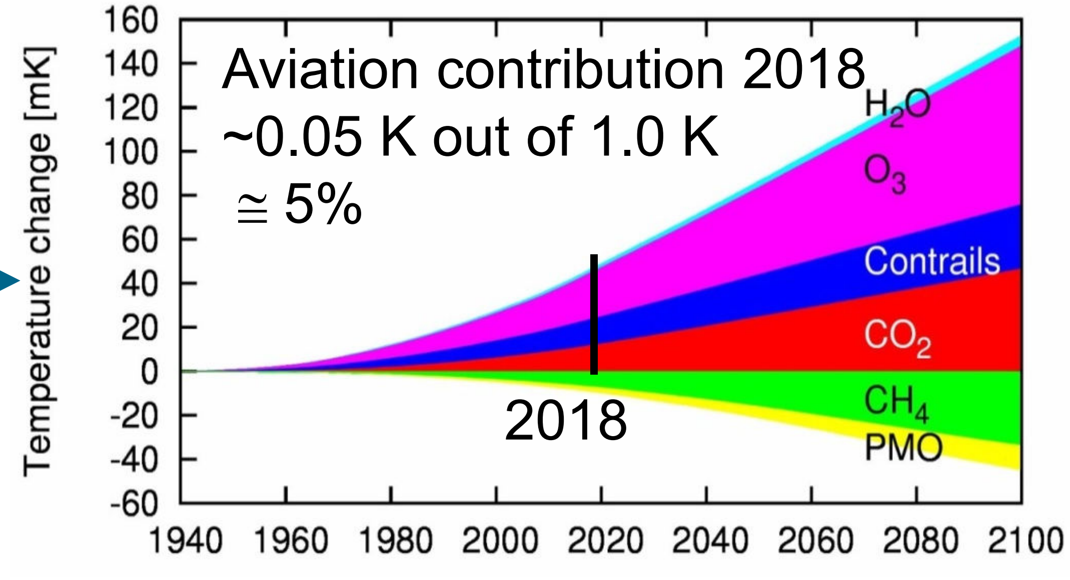
Voigt et al. 2021

How important are the aviation non-CO_2-effects?

Radiation change

Temperature change

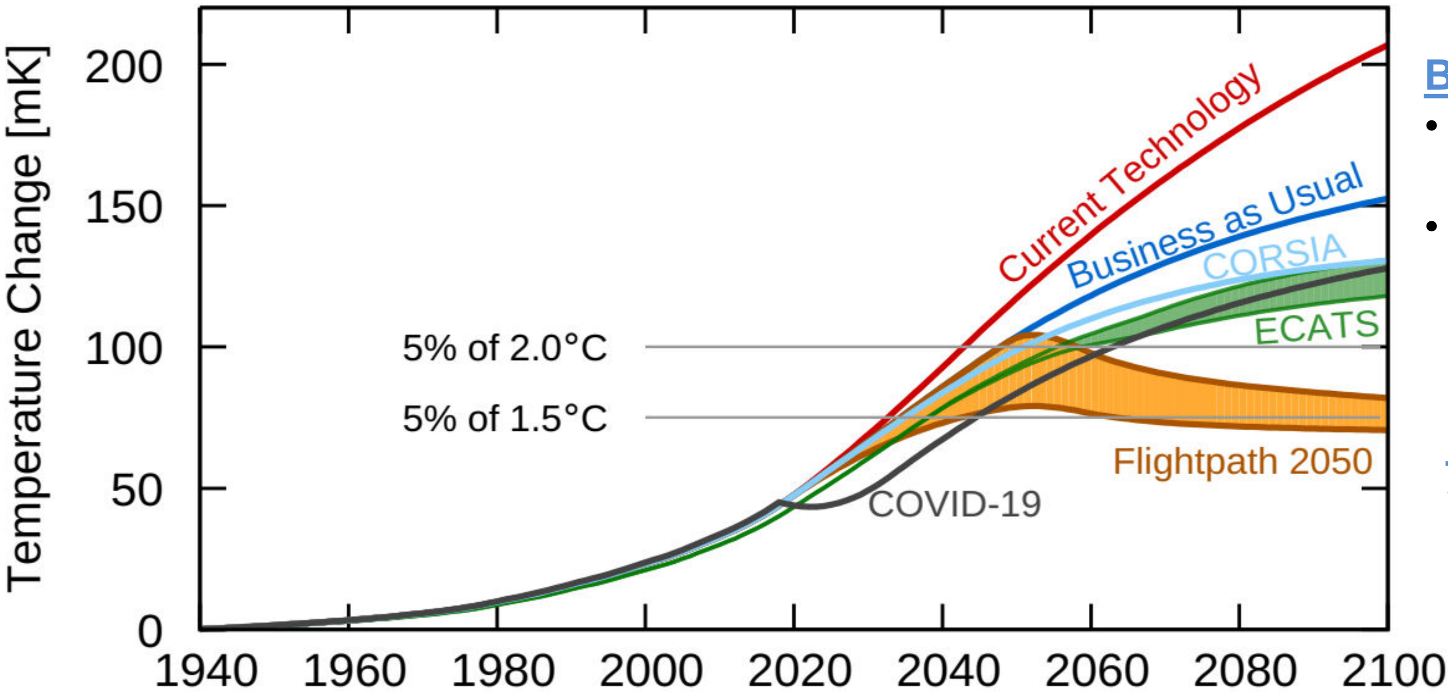




More than 50% of the aviation's climate impact results from non-CO_2 effects

Climate impact of future aviation scenarios (CO_2 and non-CO_2 effects)

Relating top-level aviation targes (CORSIA, Flightpath2050) to the Paris Agreement



Grewe et al., Nature Comm., 2021

BAU / CORSIA

- No stabilisation of the climate impact
- Largely surpassing 5% of 1.5°C and 2.0°C

Flightpath 2050

- stabilisation of the climate impact between 5% of 1.5 and 2.0°C

ECATS

- Bottom-up scenario, including state-of-theart tecnolgies, will not meet Flightpath 2050 targets.

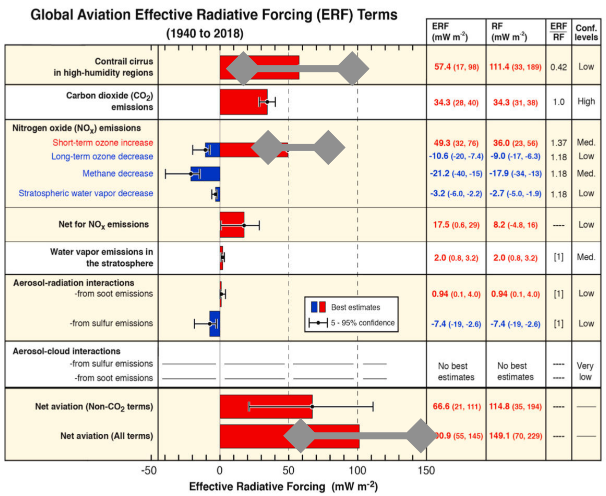
- Climate-neutral aviation (whatever that is) has to include non-CO2 effects
- Without a drastic change (e.g. H2 / large amount of SAF, etc.) the climate impact of aviation will further increase

When do we surpass a 5% climate goal?

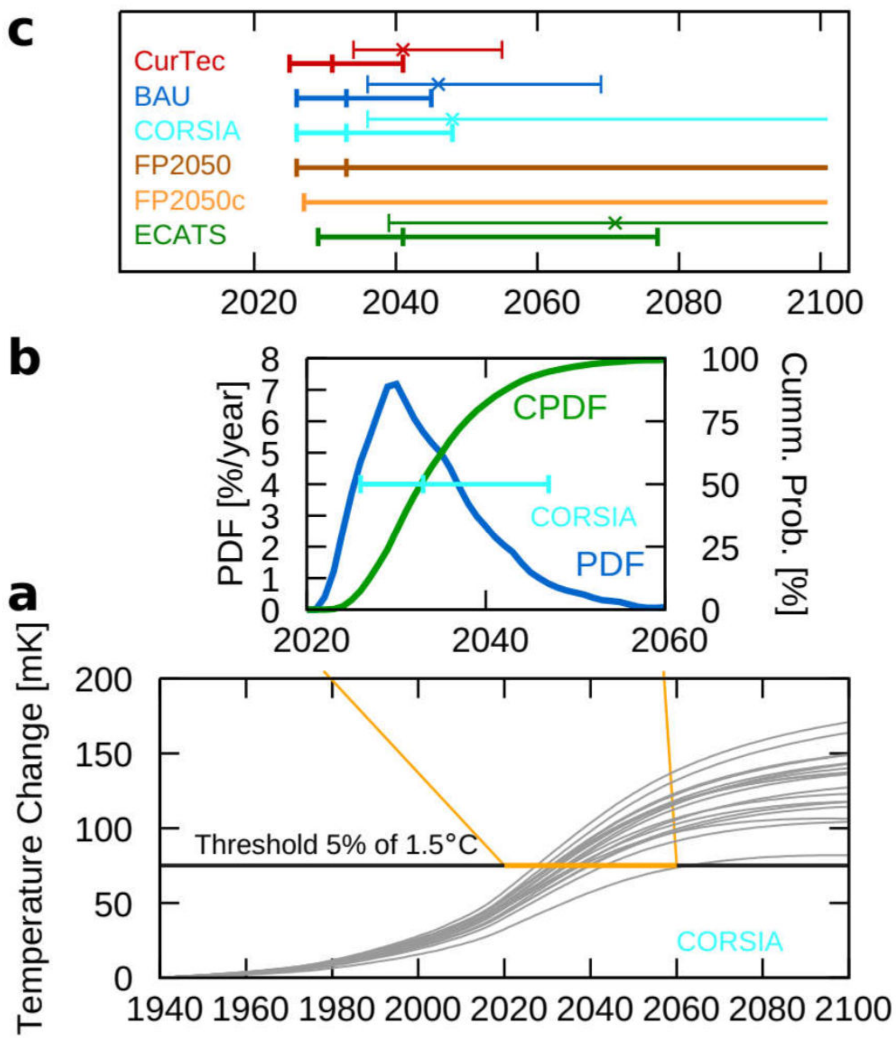
The role of atmospheric uncertainties

DLR

Uncertainies:
- Emission
- Transport pathways
- Atmospheric response / lifetime
- Radiation effects
- Temperature impacts

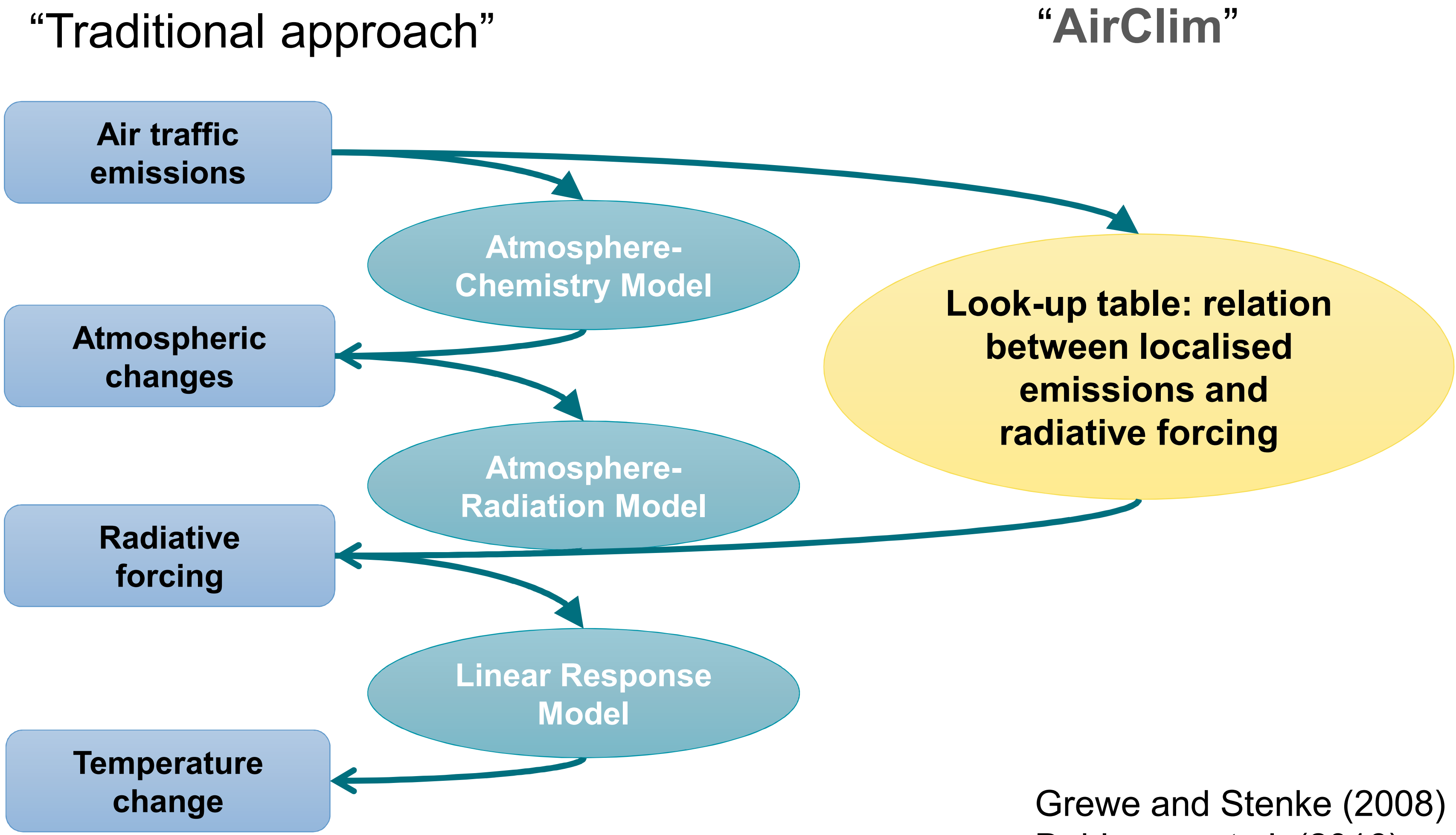


Monte-Carlo Simulation



Grewe et al. 2021

The non-linear climate response model AirClim - Basic idea

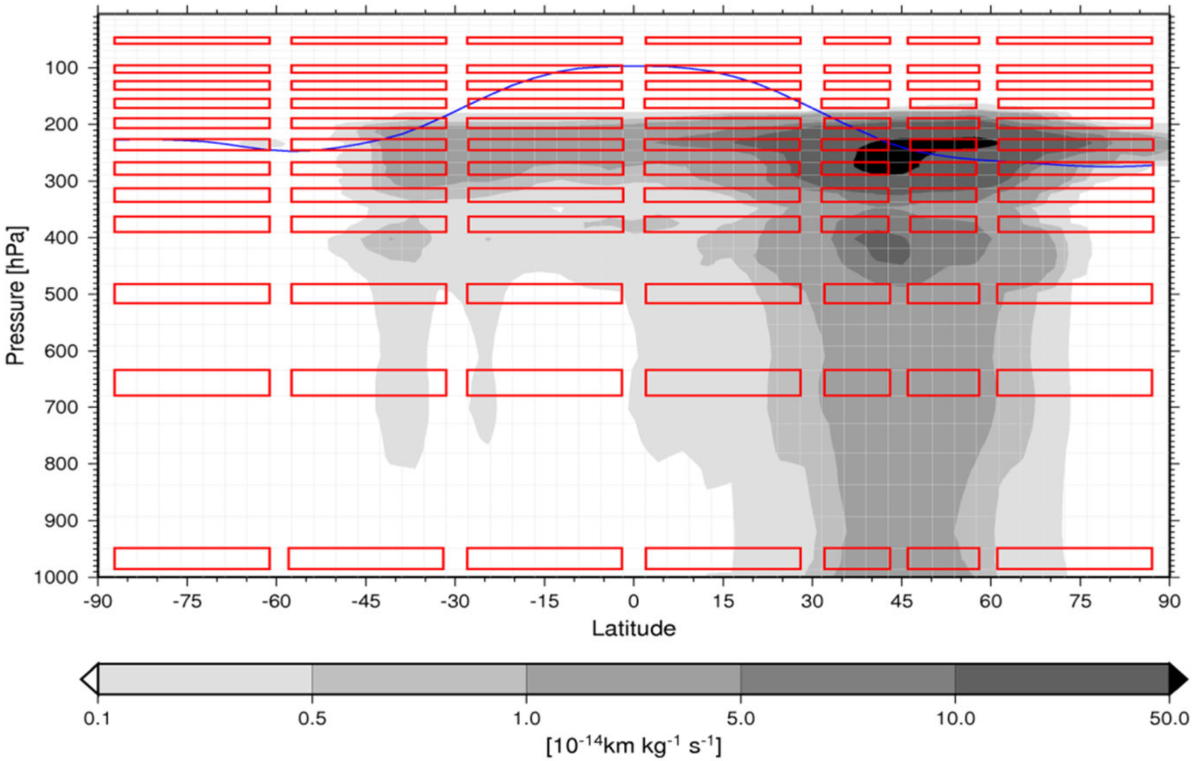


Grewe and Stenke (2008)
Dahlmann et al. (2016)

Emission locations for precalculated look-up table: subsonic case

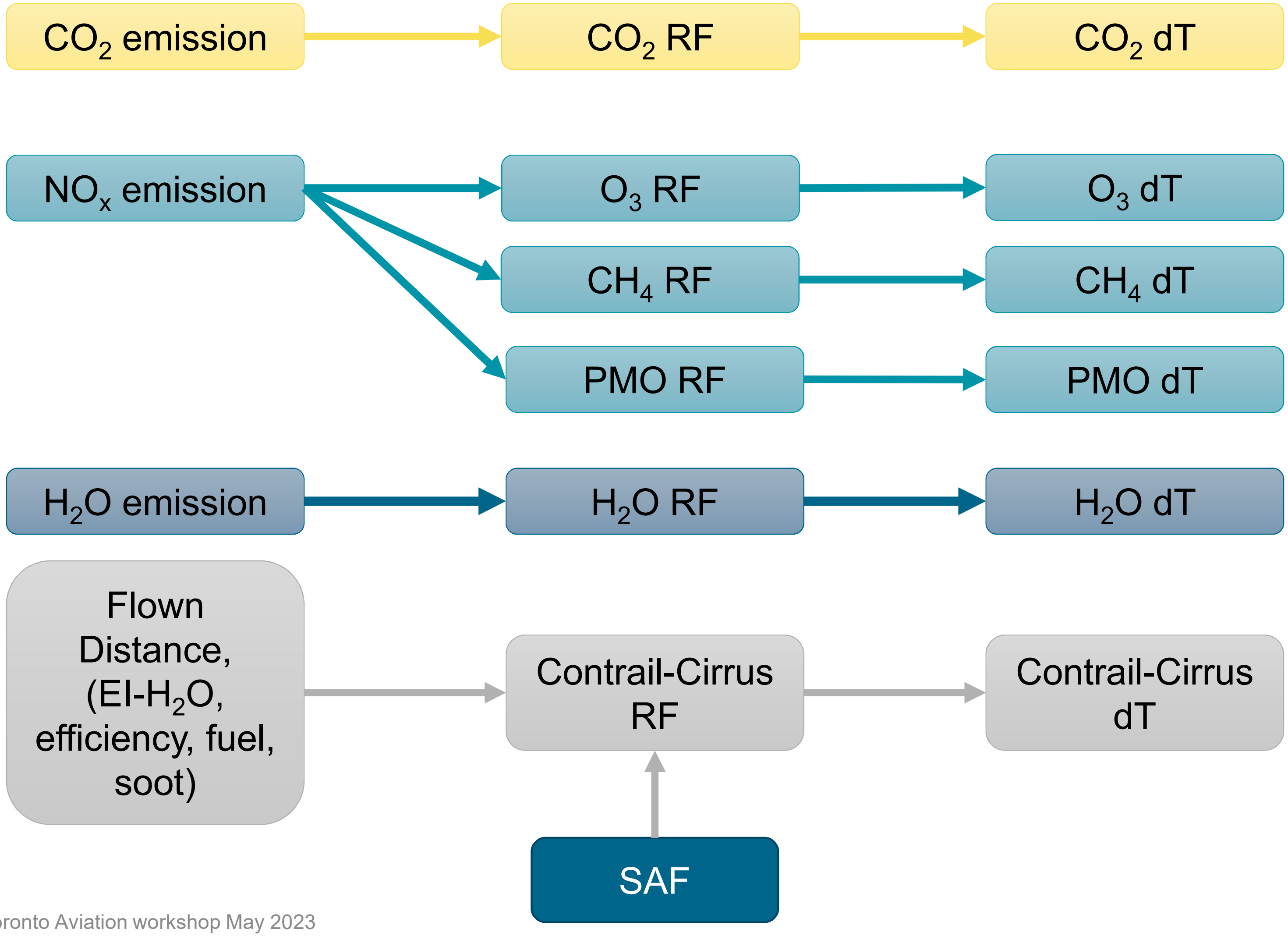
- 7 Latitudes
- 12 altitudes

- = 85 Simulations

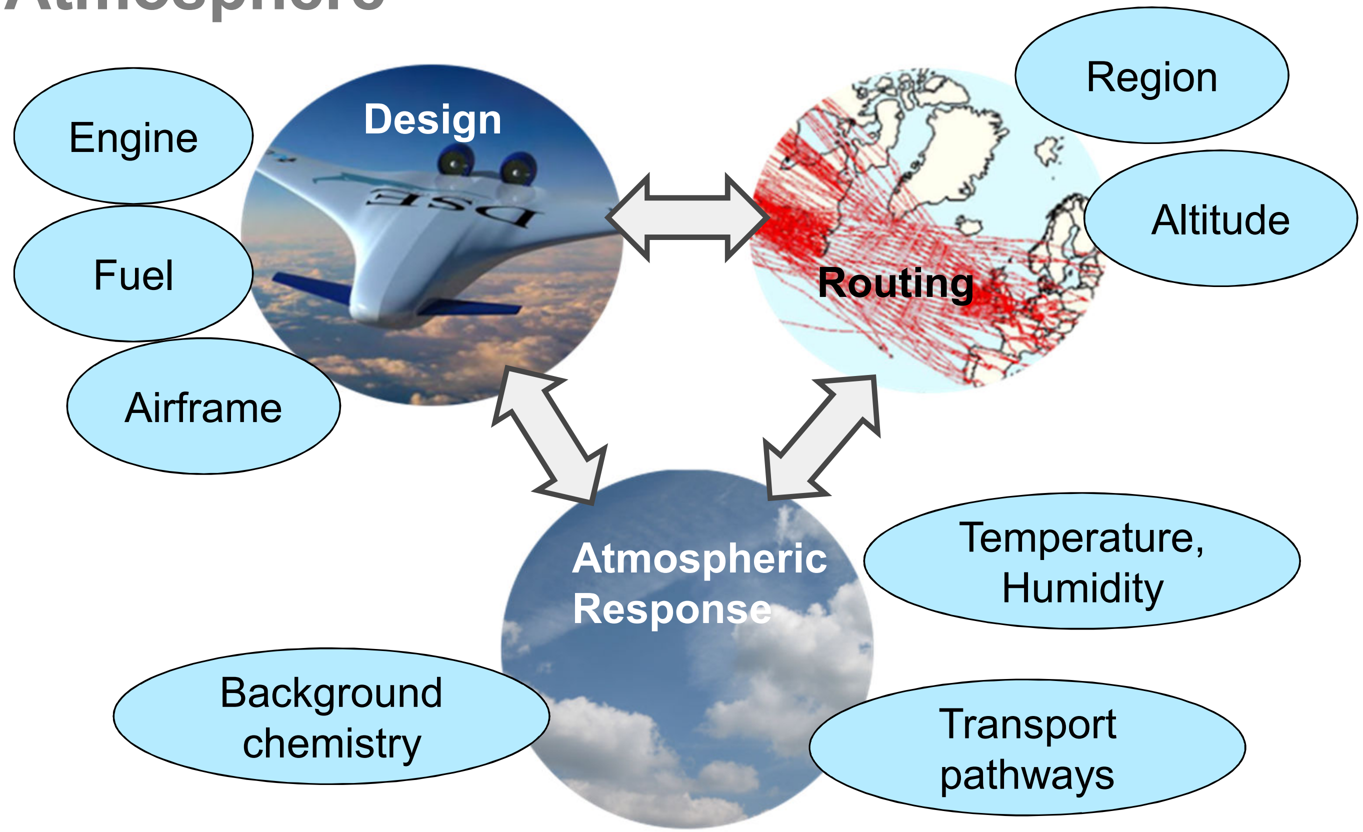


Fichter (2009)
Dahlmann et al. (2016)

Processes / Species



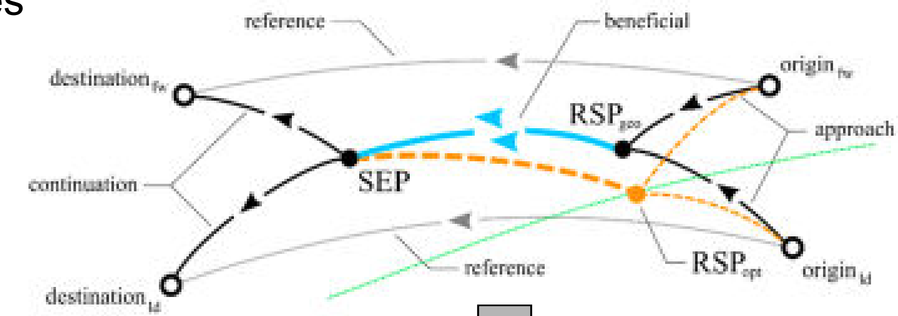
Aviation climate impact is a combination of Design – Routing – Atmosphere



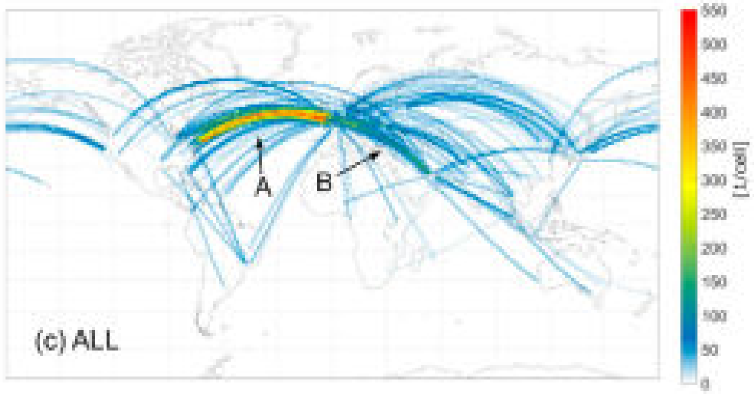
Climate Impact of Formation Flights

LuFo-Project FormIC

Analysis which routes can be linked for formation fights

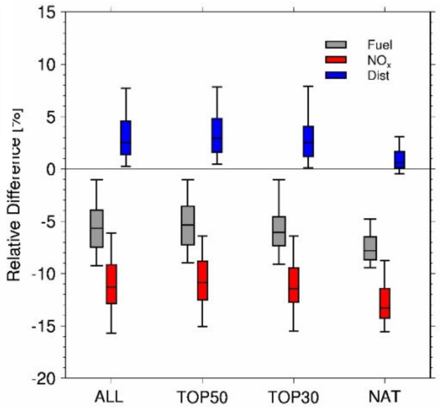


Emission inventory



Analysis

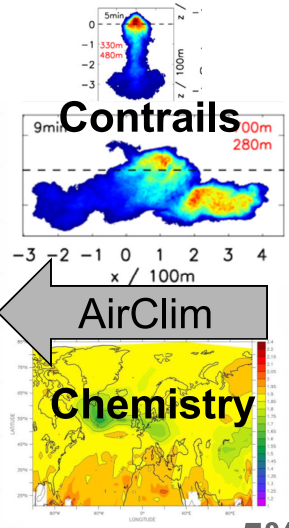
~3% more flown km

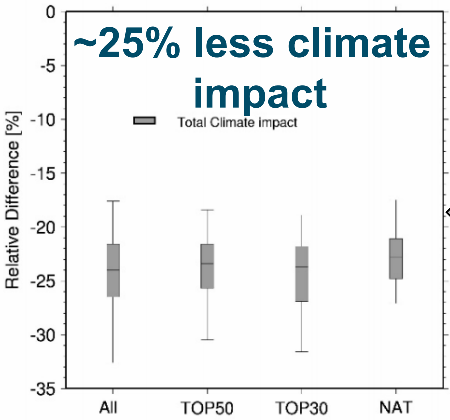


~5% less fuel

10-15% less NO_x

Marks et al. 2021
(mit Dahlmann/Grewe/Matthes/Yamashita/Unterstrasser)

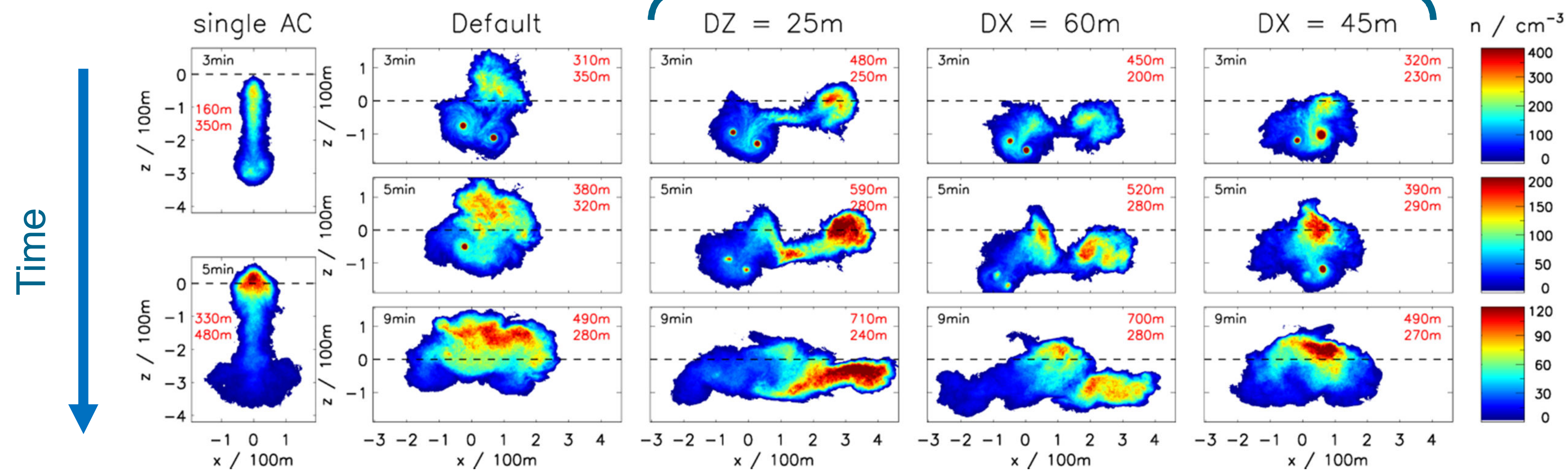




Dahlmann et al. 2020

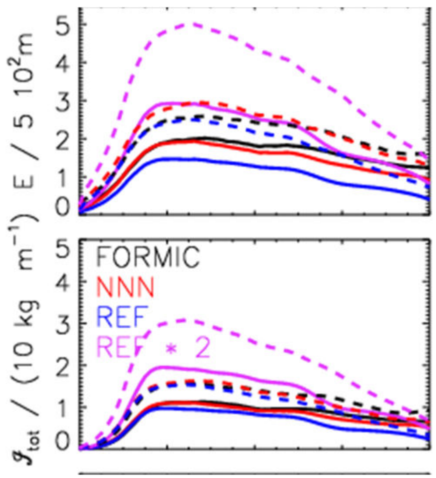
Contrail Formation during Formation Flight

Changes in the positon of the 2nd vortex



Large interaction of vortices:
Generally:

- broader contrail
- less ice mass
- lower extinction
- Smaller overall climate impact
  - 20-60%; Mean ~50%



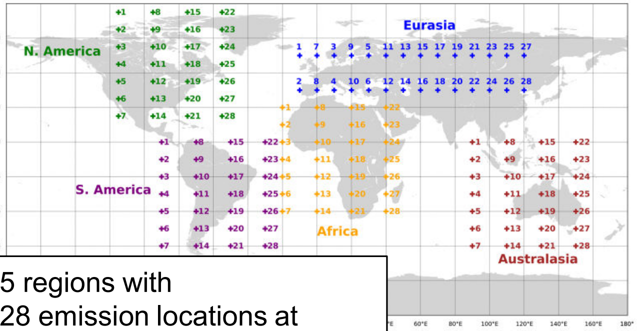
Total ice mass

Total extinction

Unterstrasser, 2020

Analysis of ozone production depending on regions: Set

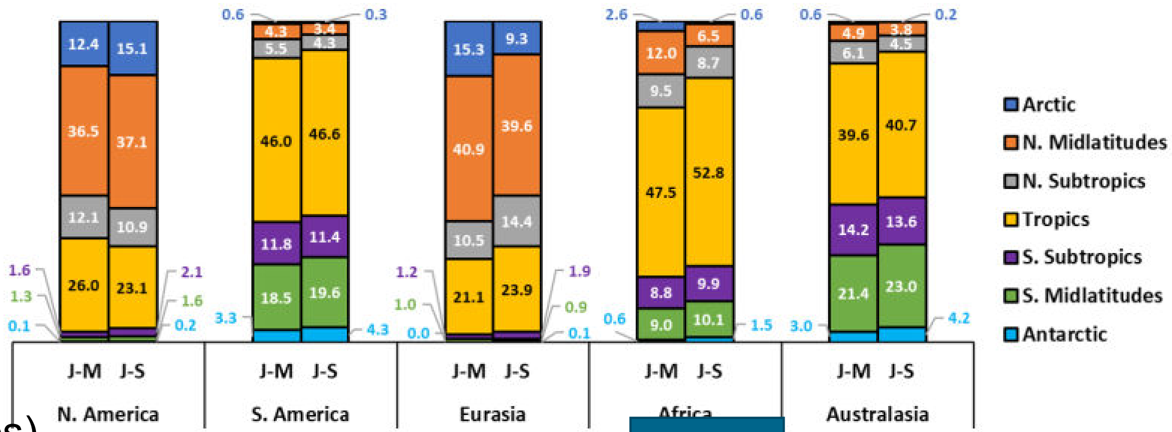
Run trajectories in EMAC



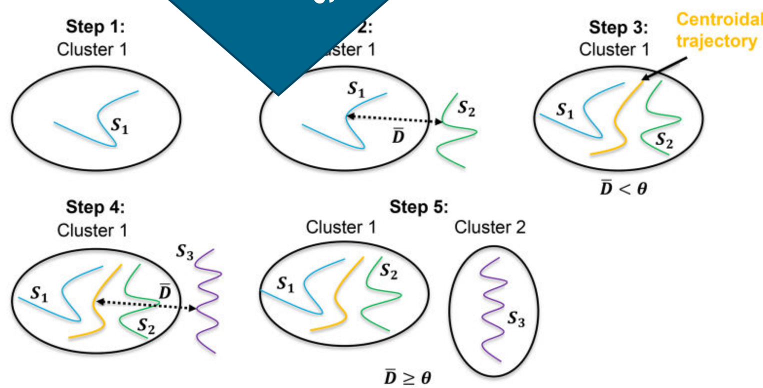
5 regions with
28 emission locations at
5 cruise levels with
50 trajectories
2 seasons (Jan/Jul)
= 70,000 trajectories

Method:
Grewe et al. (2014)
Results:
Frömming et al. (2021)
REACT4C (Matthes)

Residence times

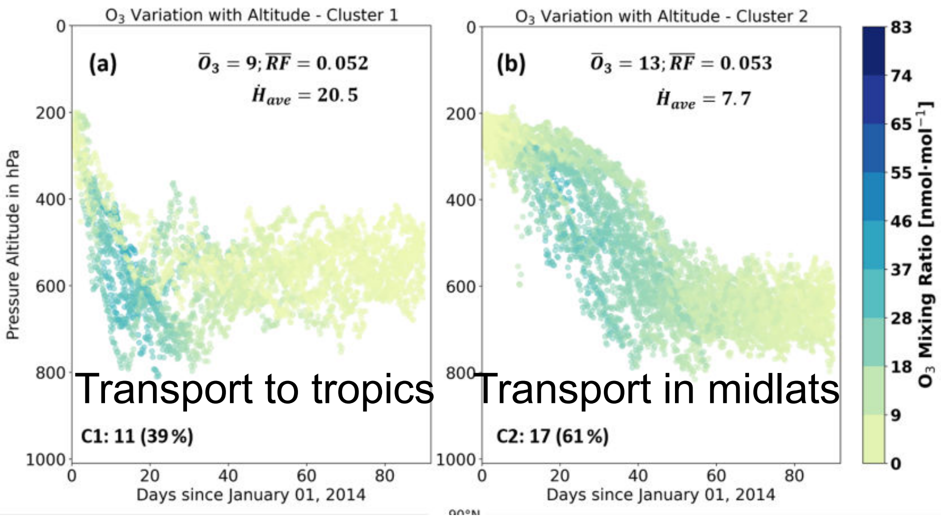


Analysis
Quick
bundle



Maruhashi et al. (2022)
ACACIA project

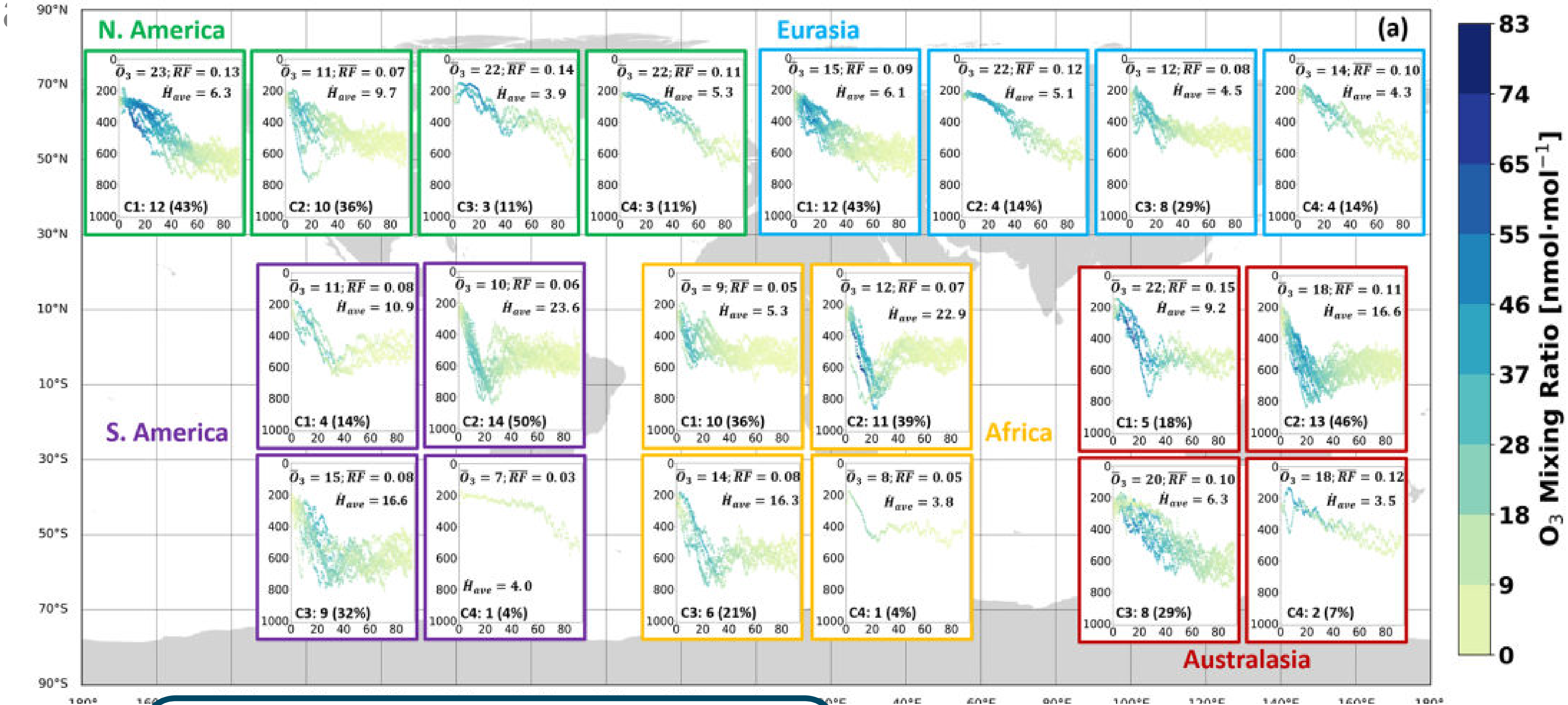
Source receptor Analysis



Transport to tropics

Transport in midlats

Analysis of ozone production depending on regions:



Basis for a revision of the NO_x-O_3 aCCFs
Rao et al. (2023)

Maruhashi et al. (2022)
ACACIA project

Inclusion of non-CO_2 aviation effects in the EU ETS

Non-CO_2 effects largely contribute to aviation climate impact

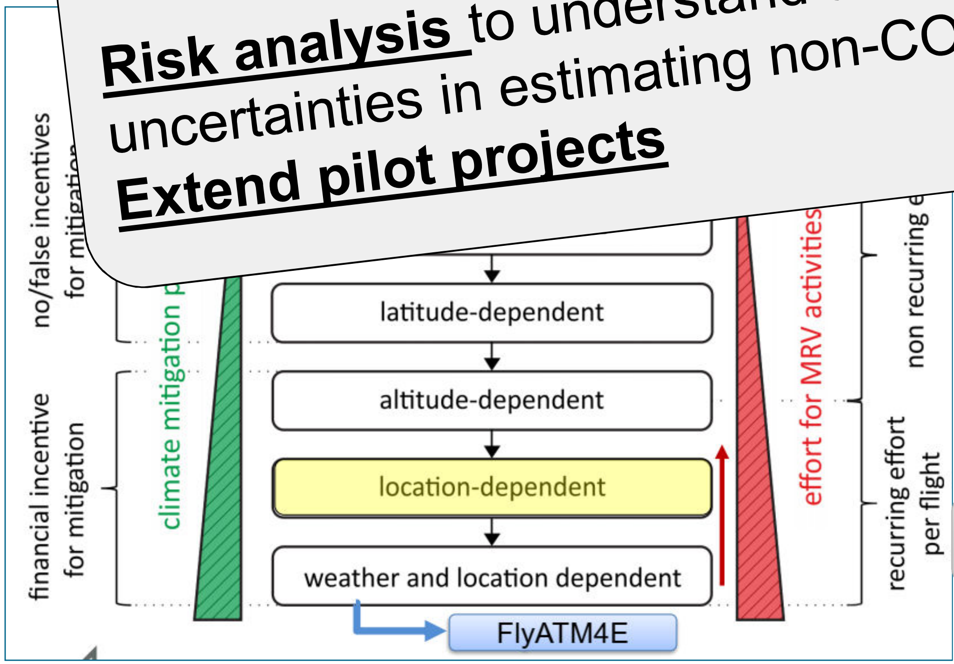
Development of CO_2 equivalent calculations that

- enable incentives for climate friendly operations&tech...
-

Next Steps

Risk analysis to understand the effects of uncertainties in estimating non-CO_2 effects

Extend pilot projects



Measure

Process Data

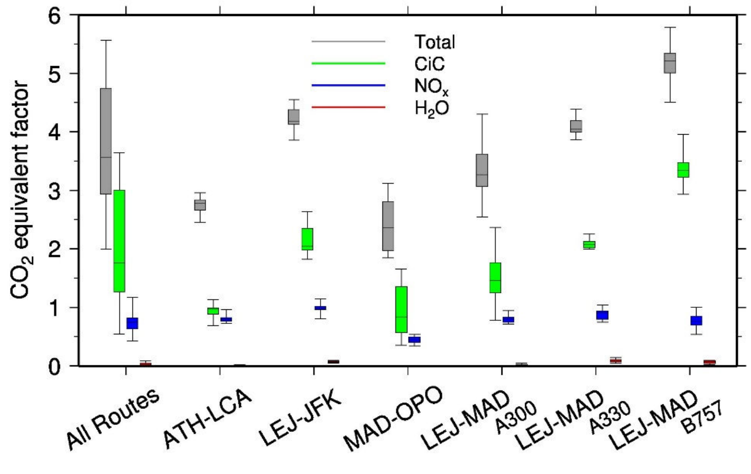
Report

Umwelt Bundesamt

Verify

Projects with UBA

- Procedure developed in cooperation with 4 DLR institutes PA, LV, AT, FW
- MRV Scheme tested with airline and UBA
  - Reporting feasible
  - Verification feasible
- Effort estimated



Summary

- Aviation climate impact due to CO_2 and non-CO_2 effects
- Non-CO2 aviation impacts are important (>50% of total climate impact)
- Scenario analysis showed that aviation will not become „climate-neutral“ without addressing non-CO_2 effects.
- OpenAirClim development is on-going
- Assessment of mitigation options show different effects for CO_2 and non-CO_2 : Formation flight: win-win! Often we ave trade-offs
- NO_x- Ozone relations gives
  - A better understanding of weather related effects
  - Provides a basis for revision of algorithmic climate change functions
- More work available on: Climate Metrics, single flight analysis, route optimisation ….. See also sigrun Matthes talk