CLIMATE IMPACT AND MITIGATION MEASURES

More and Less Summer School, Blumenthal

Dahlmann, Katrin, Atmospheric Physics, DLR, 06.09.2023

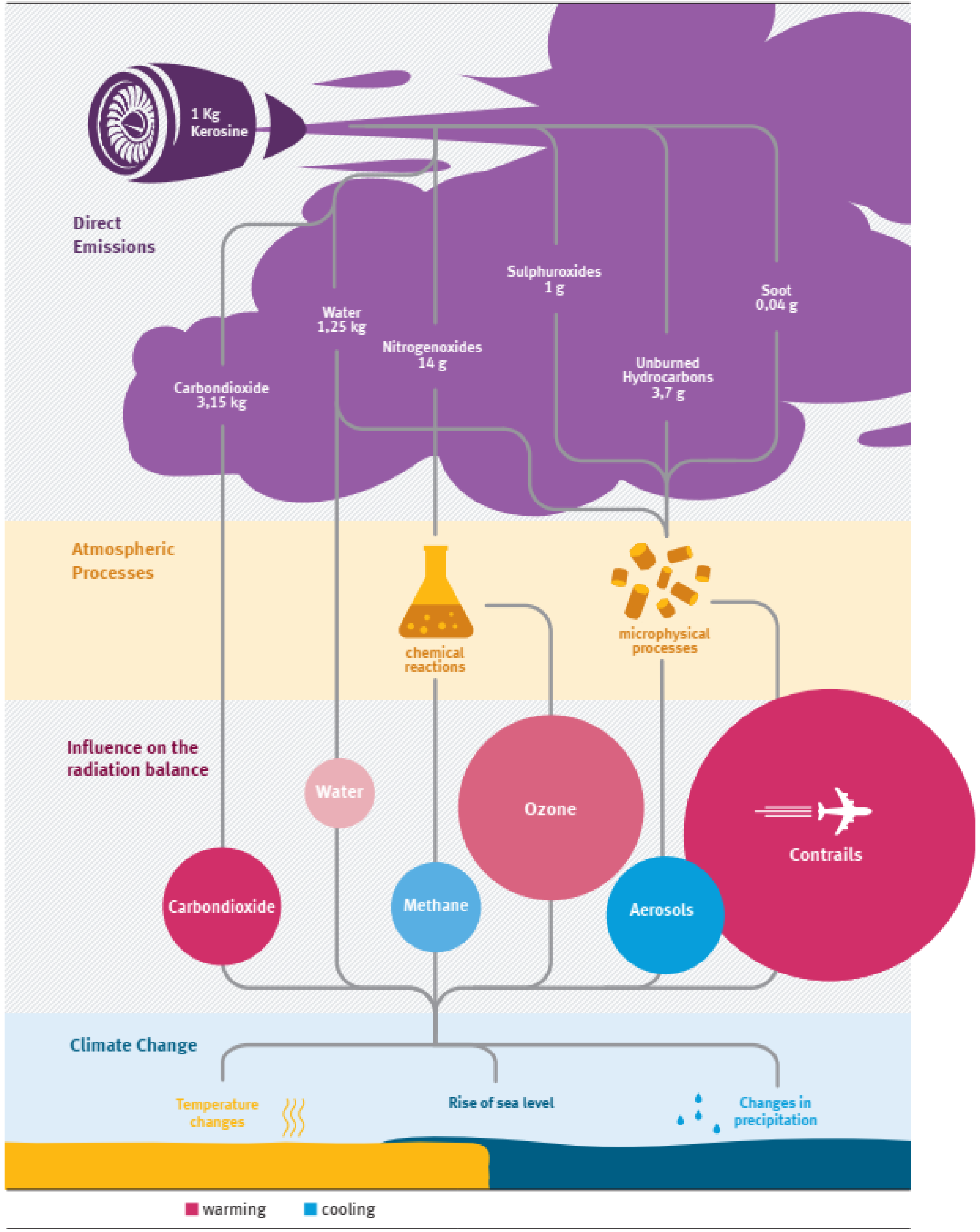
Outline

- Climate impact of aviation
- Mitigation measures
- Climate metrics

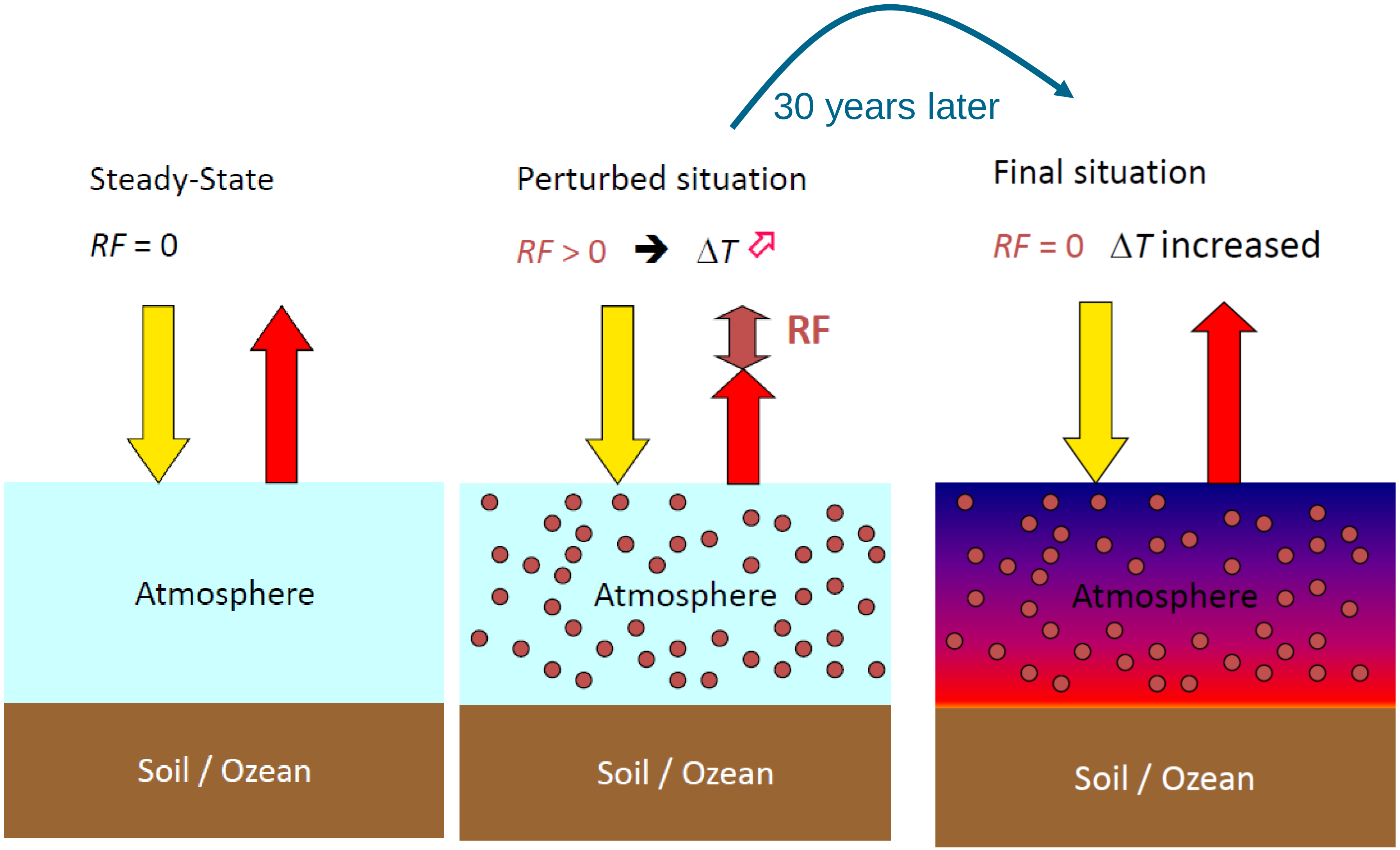
CLIMATE IMPACT OF AVIATION

Source: pexels.com

Aviation climate impact



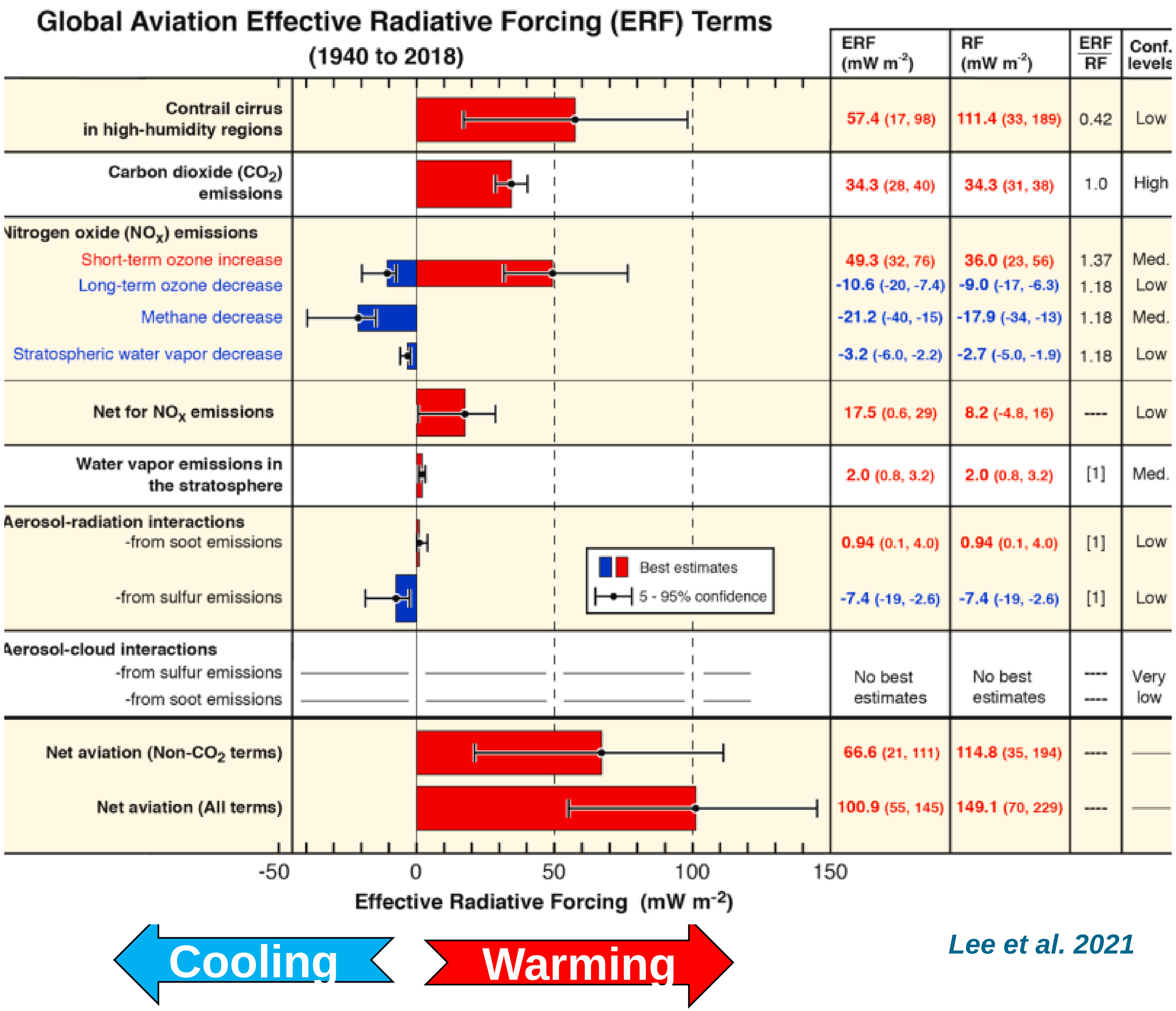
Radiative Forcing to temperature change



$$\Delta T = \lambda_x \, RF$$

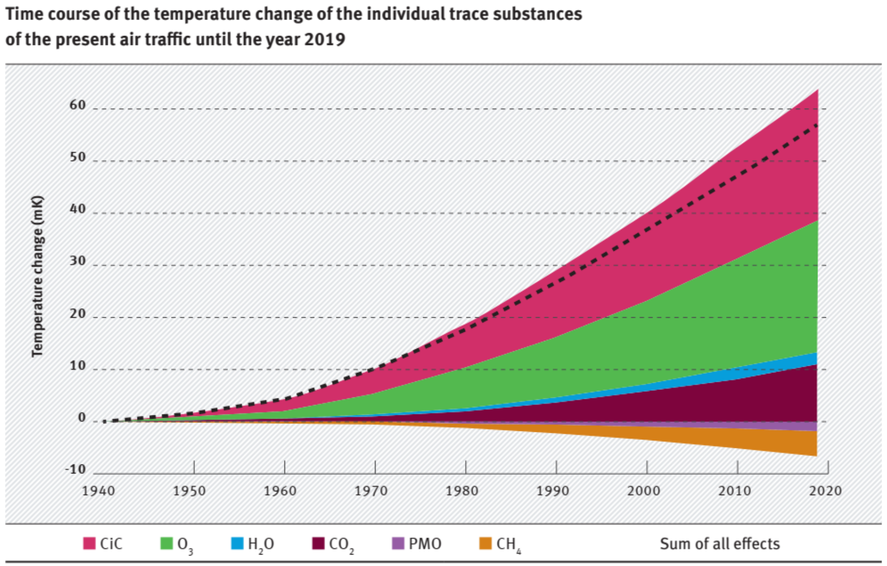
Climate sensitivity
(differ for different climate species)

Aviation climate effects



Lee et al. 2021

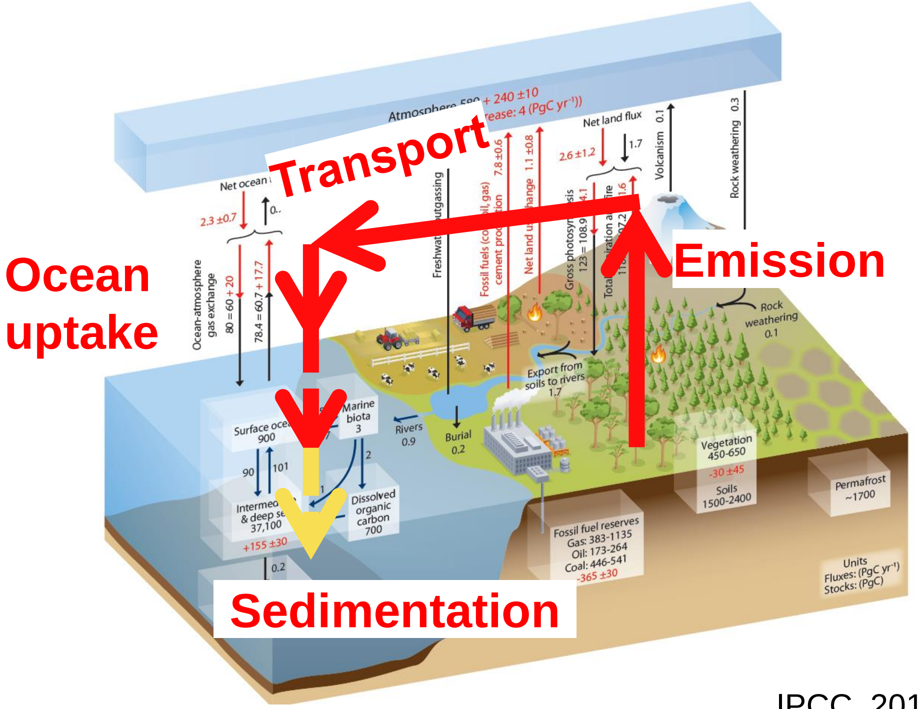
Efficacy=$\lambda_{spec}/\lambda_{CO2}$



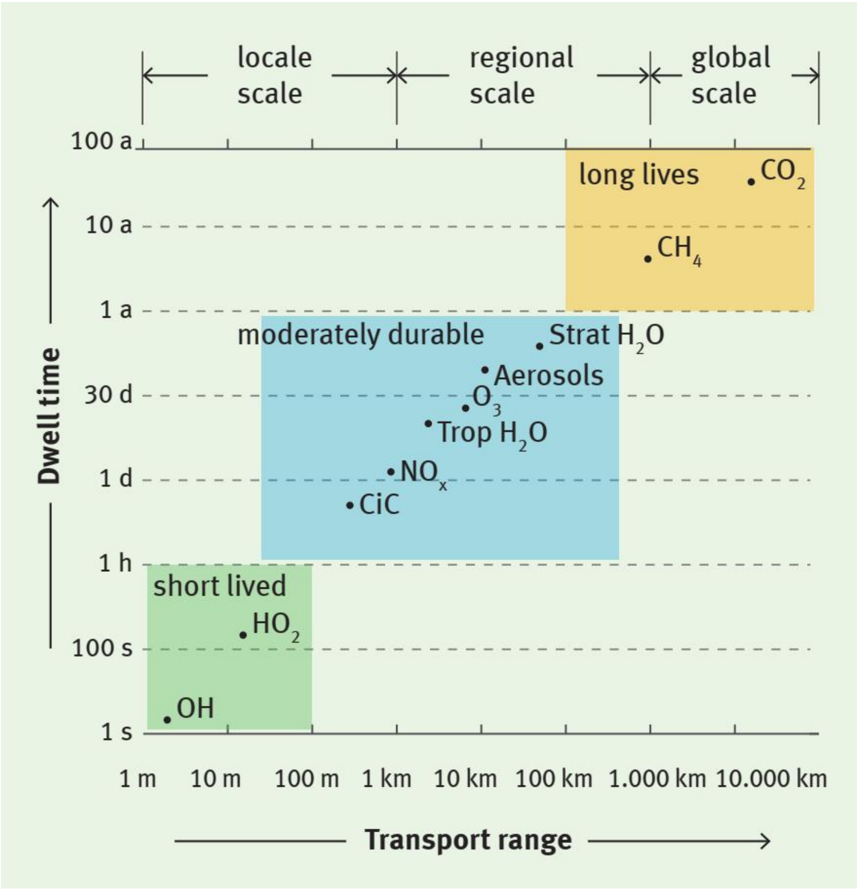
About 5% of global anthropogenic temperature change is caused by aviation emissions

Lifetime of perturbations

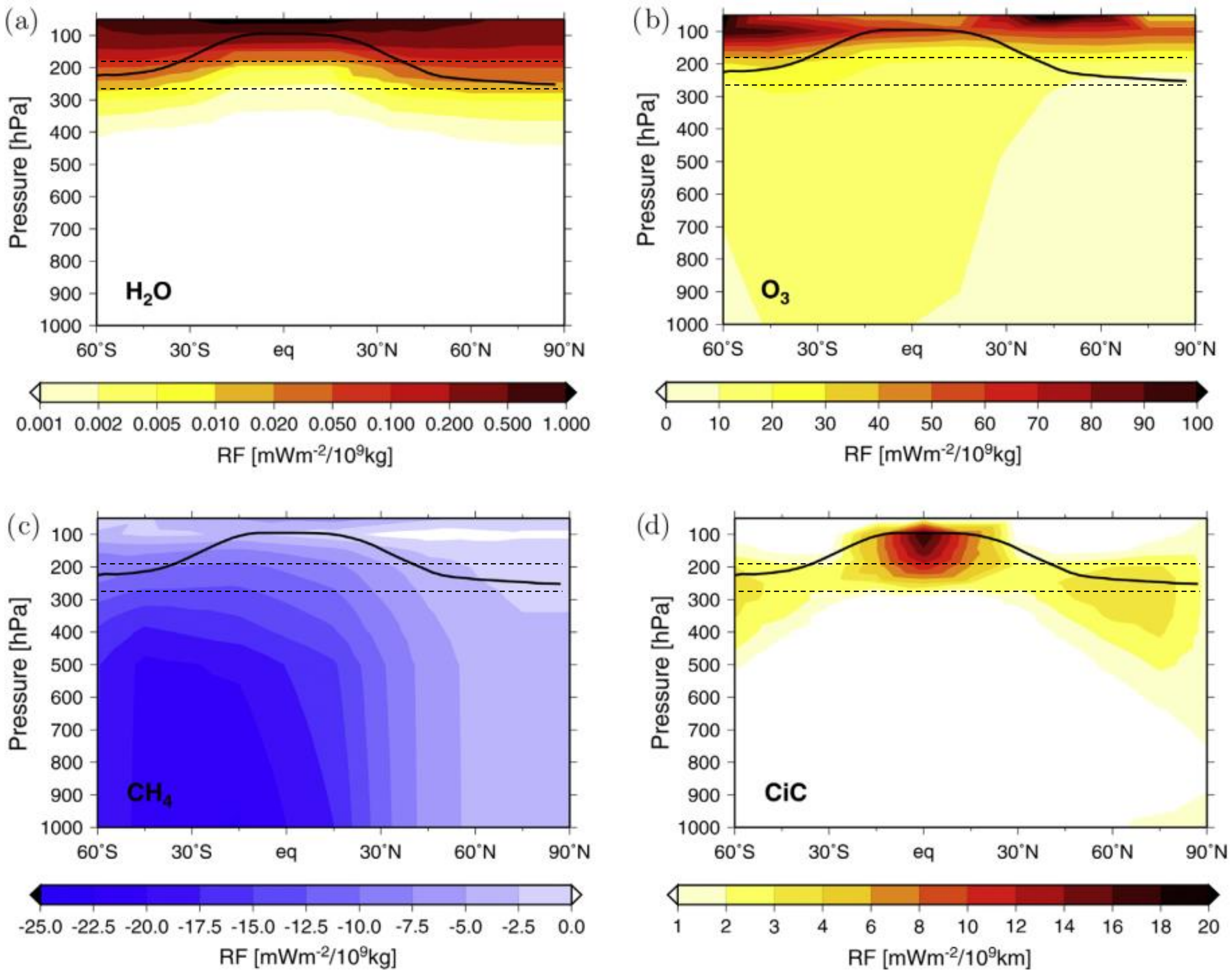
- CO_2: 1-1 000 000 years (Biosphere, Ocean, sediment, solid rock)
- Methane and primary mode ozone (depletion): years
- Water vapour and shortlived ozone production: weeks
- Contrail cirrus: hours to days



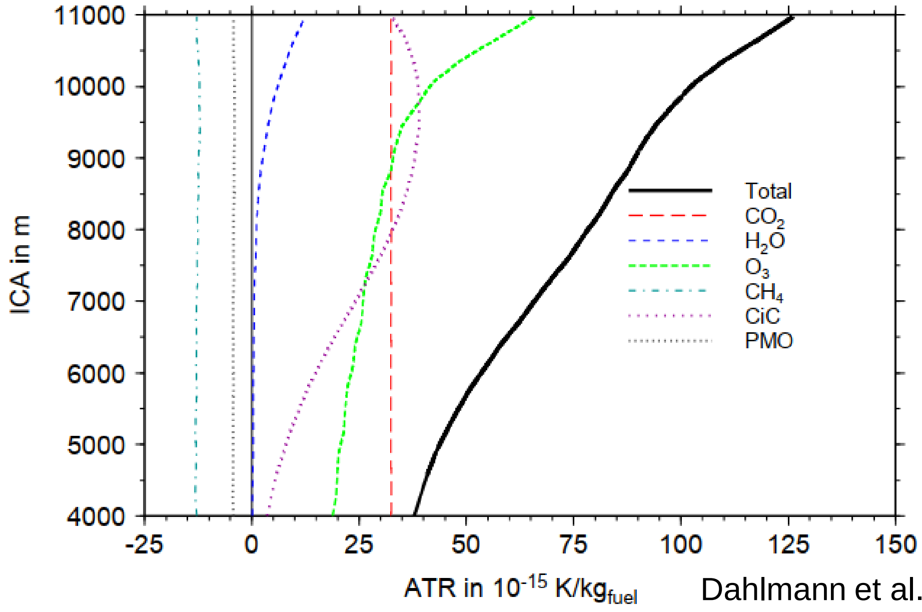
IPCC, 2013



Altitude dependency – climatology based



Dahlmann et al., 2016

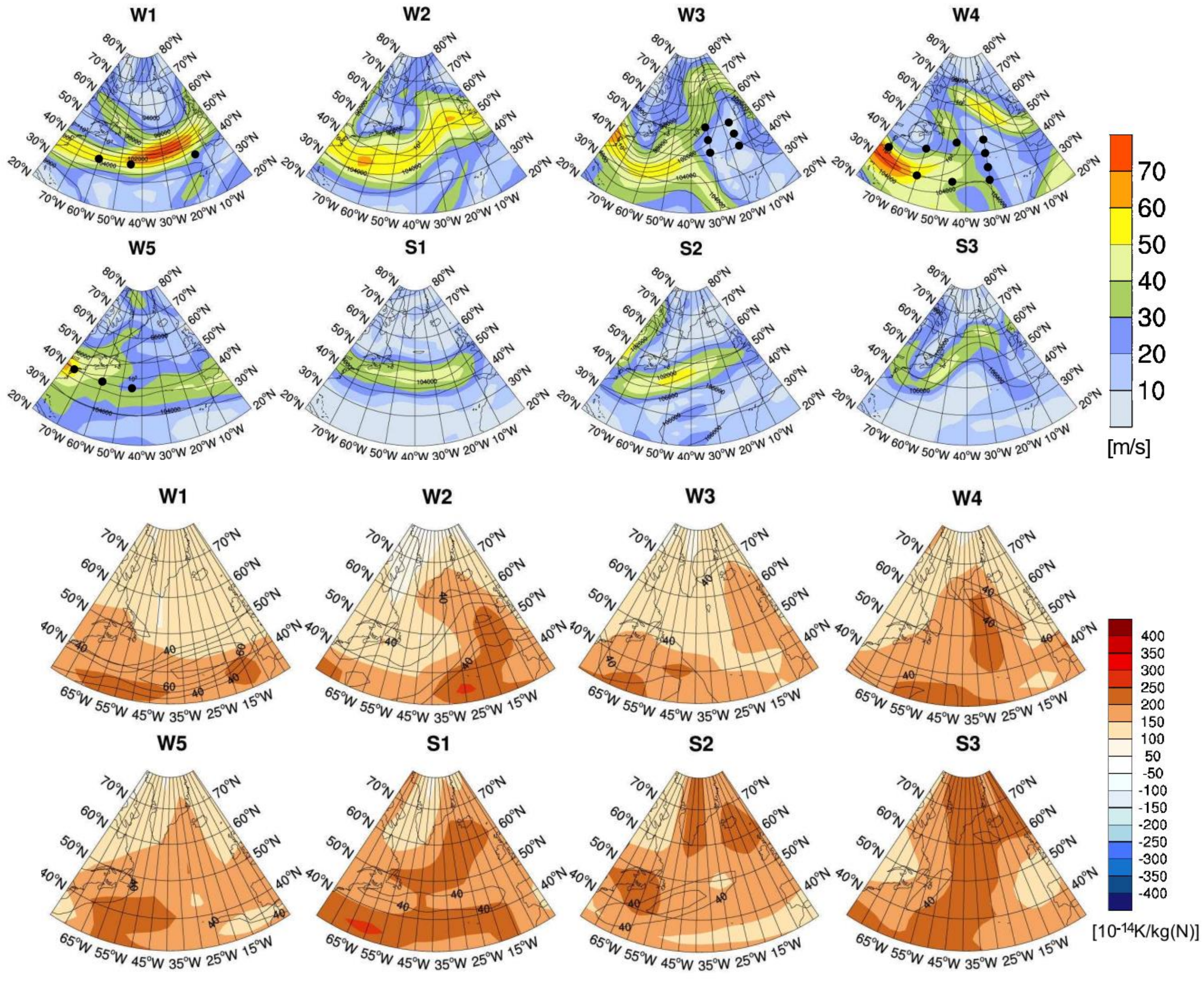


Dahlmann et al., 2016

Example for flight JFK-MUC

Weather data and Ozone Climate-Change-Functions

Frömming et al. 2021



Climatology of aviation weather situations:
Winter W1-W5
Summer S1-S3
University Reading
Irvine et al. 2013

Contribution of a local NO_x emission to climate change via ozone formation

- **Clear relationship between weather and CCFs**

This project has received funding from the SESAR Joint Undertaking under grant agreements No 699395 and No 891317 under European Union's Horizon 2020 research and innovation programme.

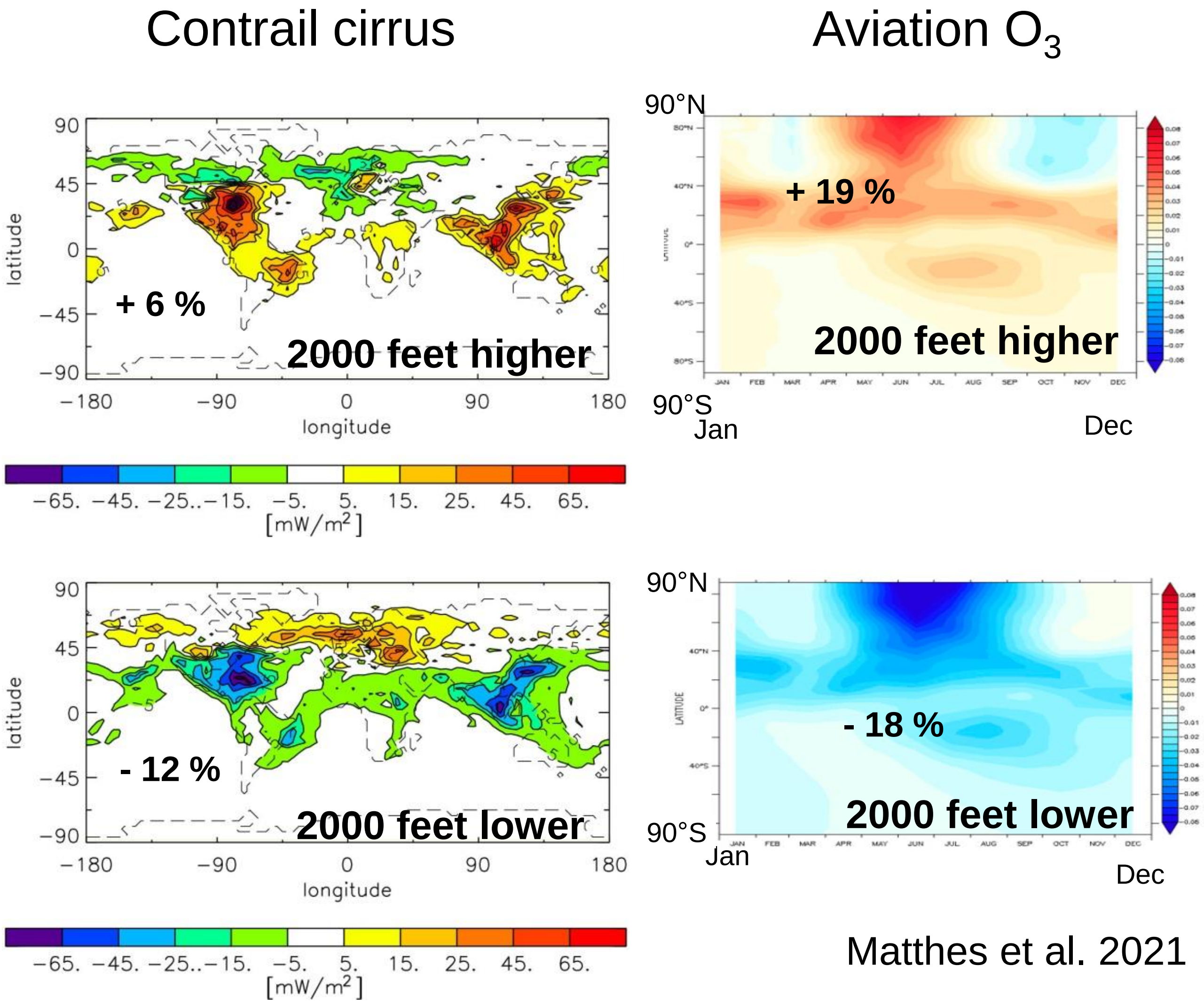
Regional variations of non-CO_2 effects

- Climate impact of non-CO_2 effects depend on emission location and weather

⇨ Climate impact not directly related to amount of emissions

- Counteracting effects:
  - Flying higher: fuel cunsumption decreases

  ⇔ Climate impact of CiC and ozone increases

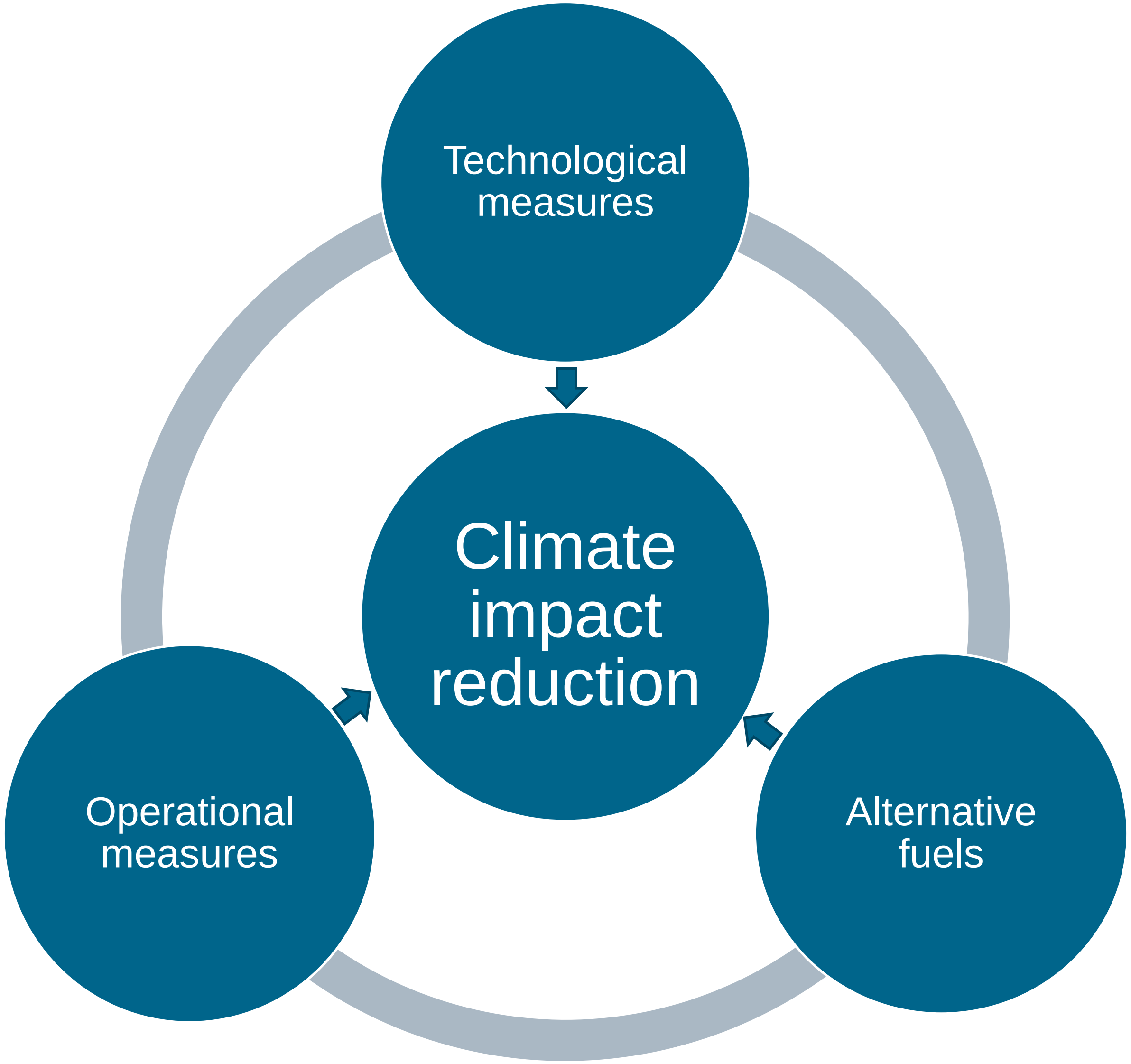


Matthes et al. 2021

MITIGATION MEASURES

Source: DLR

Mitigation measures

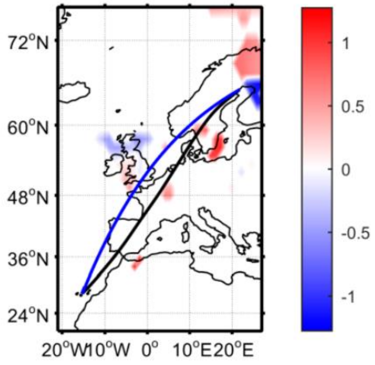


Operational measures

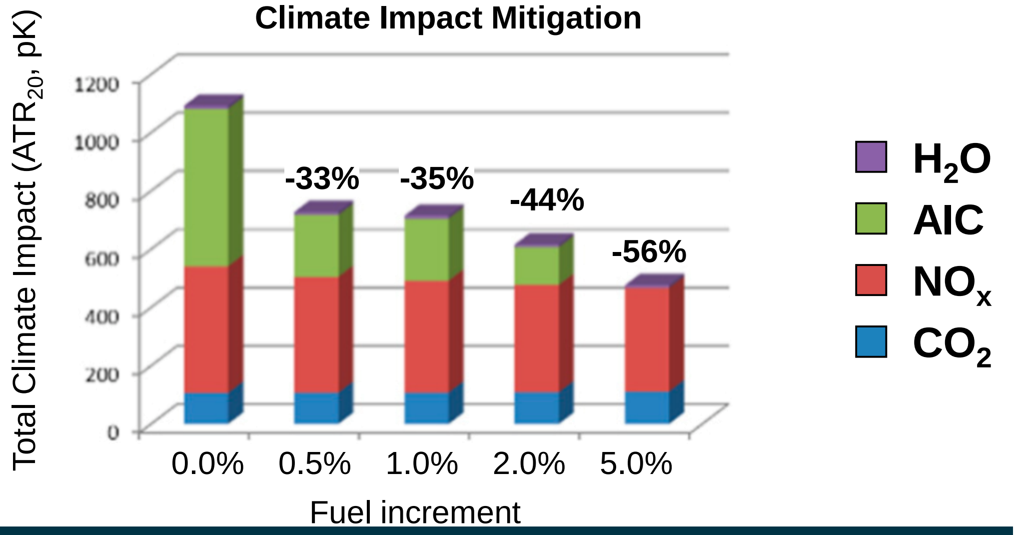
- Efficient flight guidance
  - Less detours -> less emissions
- Climate optimzed flights
  - One Day Case Study of European Air Traffic on 18 December 2015

Eurocontrol (2014)

Example: Lulea – Gran Canaria (ESPA-GCLP)
Contrails-dominated climate impact



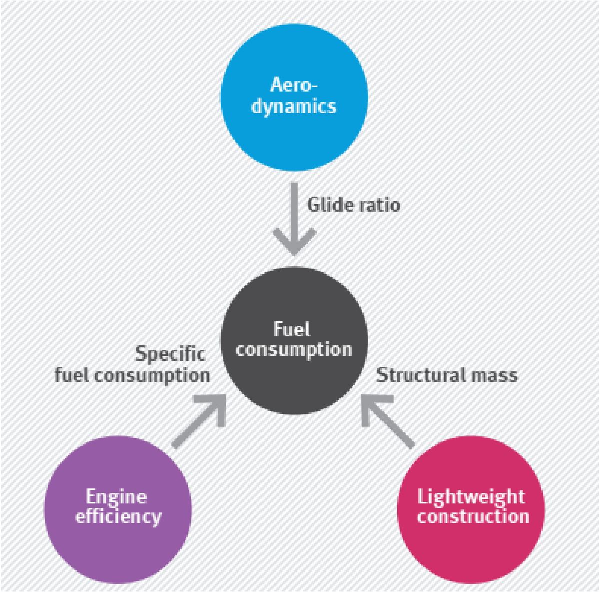
Matthes et al., 2020

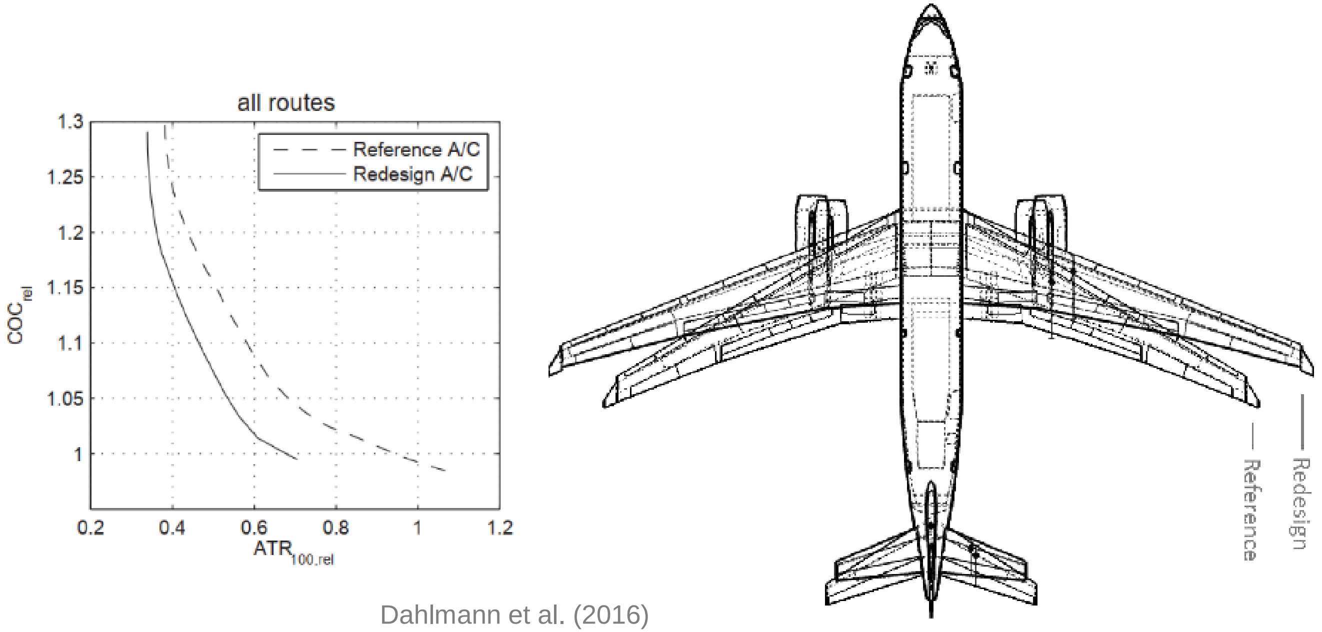


- **Climate-optimized routings can mitigate the total climate impact significantly**
- **The total climate impact of a flight can decrease despite increasing emissions** (e.g. -35% ATR_{20} for +1% fuel increase)
- **Climate-optimized routings might not be cost-optimal** (need for market-based / policy measures)

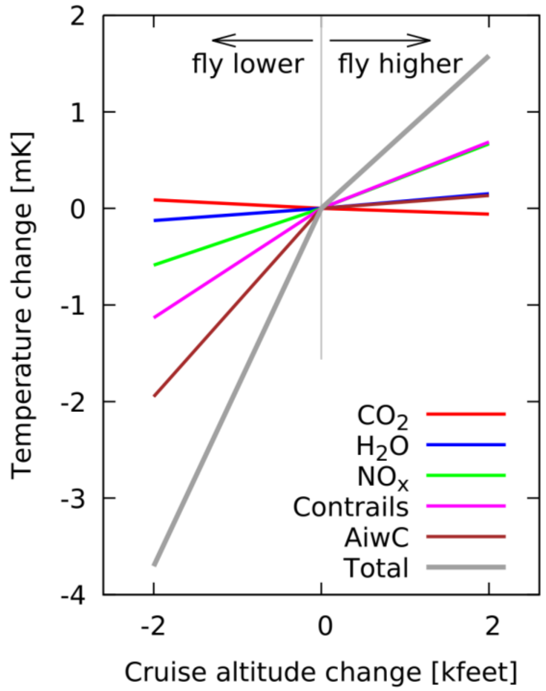
Technological measures

- Reducing specific fuel consumption
- Climate optimized aircraft design
  - Flying in lower altitudes -> aircraft fly outside design space
  - Optimized aircraft design can reduce tradoffs between fuel consumption and climate impact





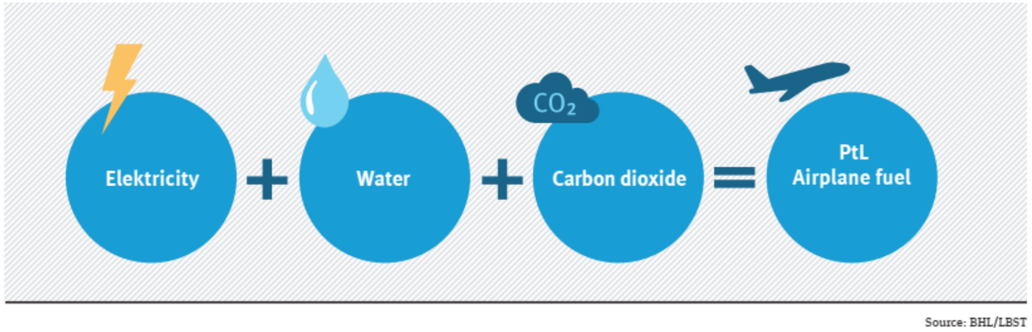
Dahlmann et al. (2016)

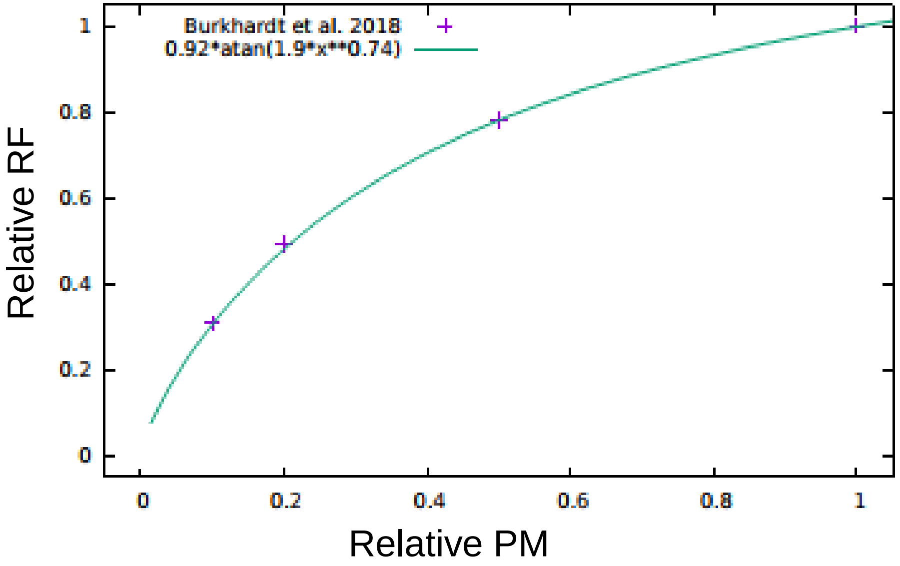


Matthes et al. 2021

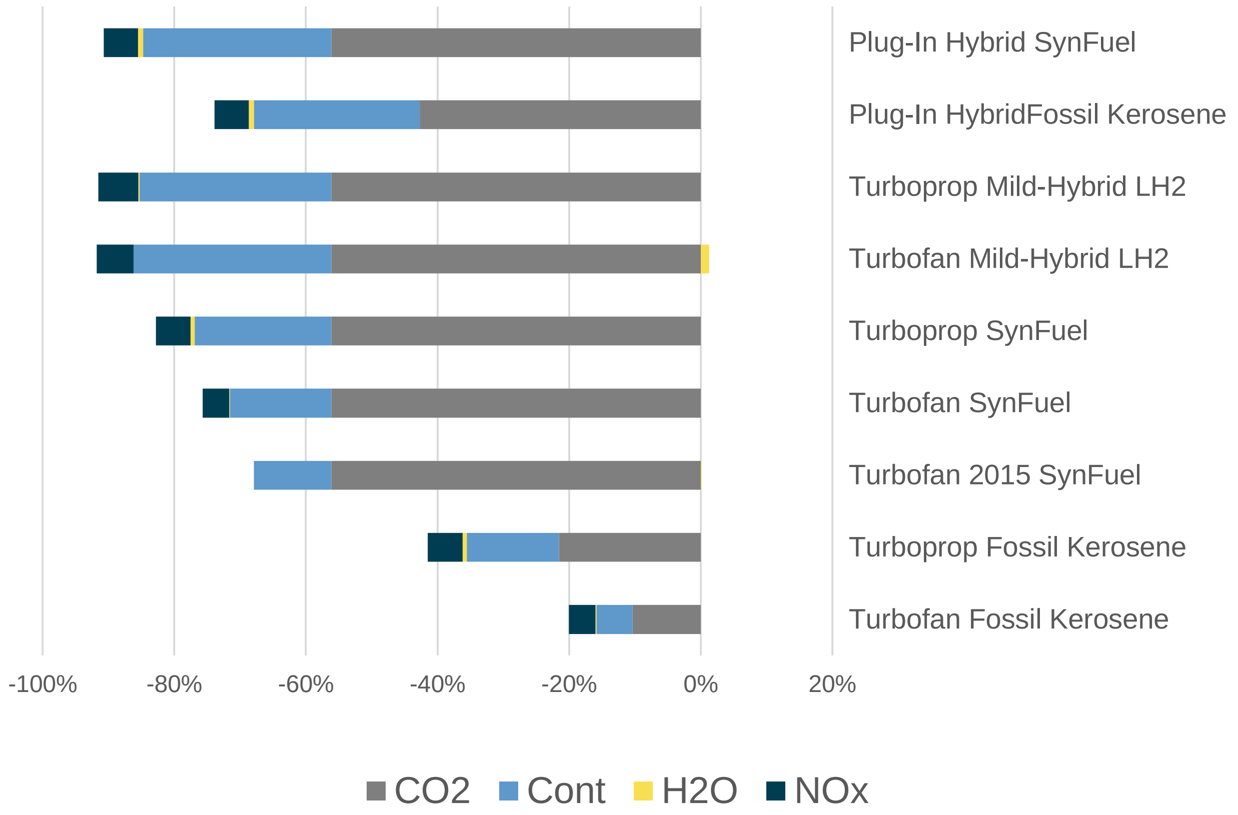
Alternative Fuel

- Climate neutral CO_2 (at least partly)
- Less Particle emissions
  - Less climate impact of contrail cirrus
- Climate neutral CO_2 would decrease trade off between non-CO_2 reduction and CO_2 increase





EXACT- different technologies and fuels



- Climate impact can be reduced by up to 90% using CO_2 neutral fuel (SynFuel or LH2)

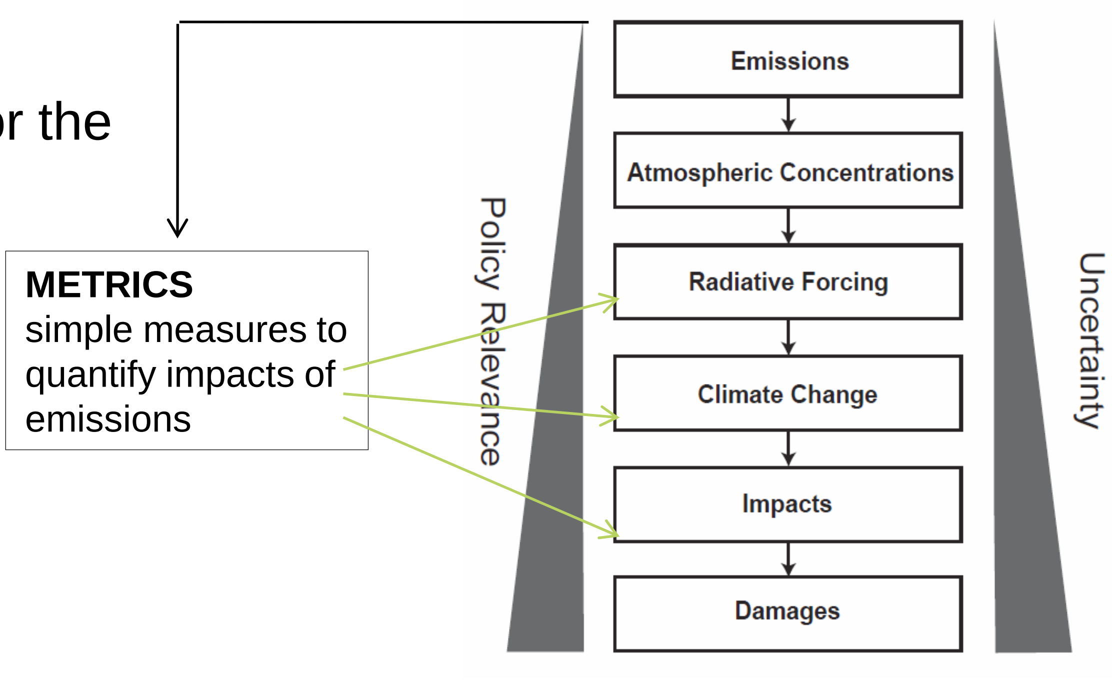
METRICS

Source: pexels.com

Climate metrics

- Mitigation measures often
  - reduce impact of single species
  - cause Tradeoffs between different species
- Climate impact differ
  - Warming and cooling
  - Different lifetime
  - Different climate sensitivity

➢ quantitative measure of climate effects is needed for the comparison

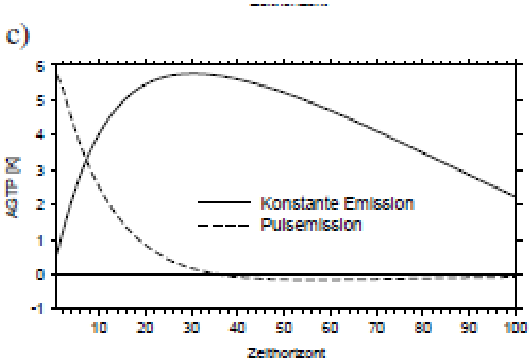


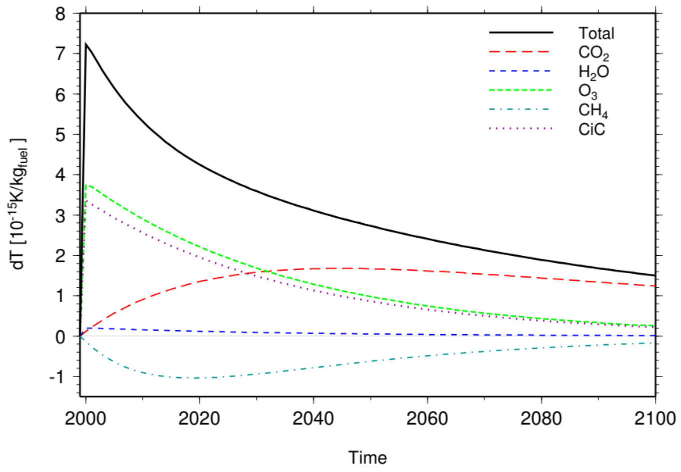
What is a climate metric?

- Metric = quantitative measure of climate effects
- How to measure ‚climate effect‘?
  - Which climate indicator?
    - Radiative Forcing or Temperature change?
    - At a point in time or over a time span?
  - Which emission development?
    - For pulse emissions or sustained emissions?
  - Which time horizon?
    - In 20 years or in 100 years?
- Different metrics relate to different aspects of climate change!
- The wording „climate change“ is not well-defined, somehow fuzzy!

$$\Delta RF_{spec}(t) \longrightarrow GWP = \frac{\int_0^H RF_{spec}(t)dt}{\int_0^H RF_{CO_2}(t)dt}$$

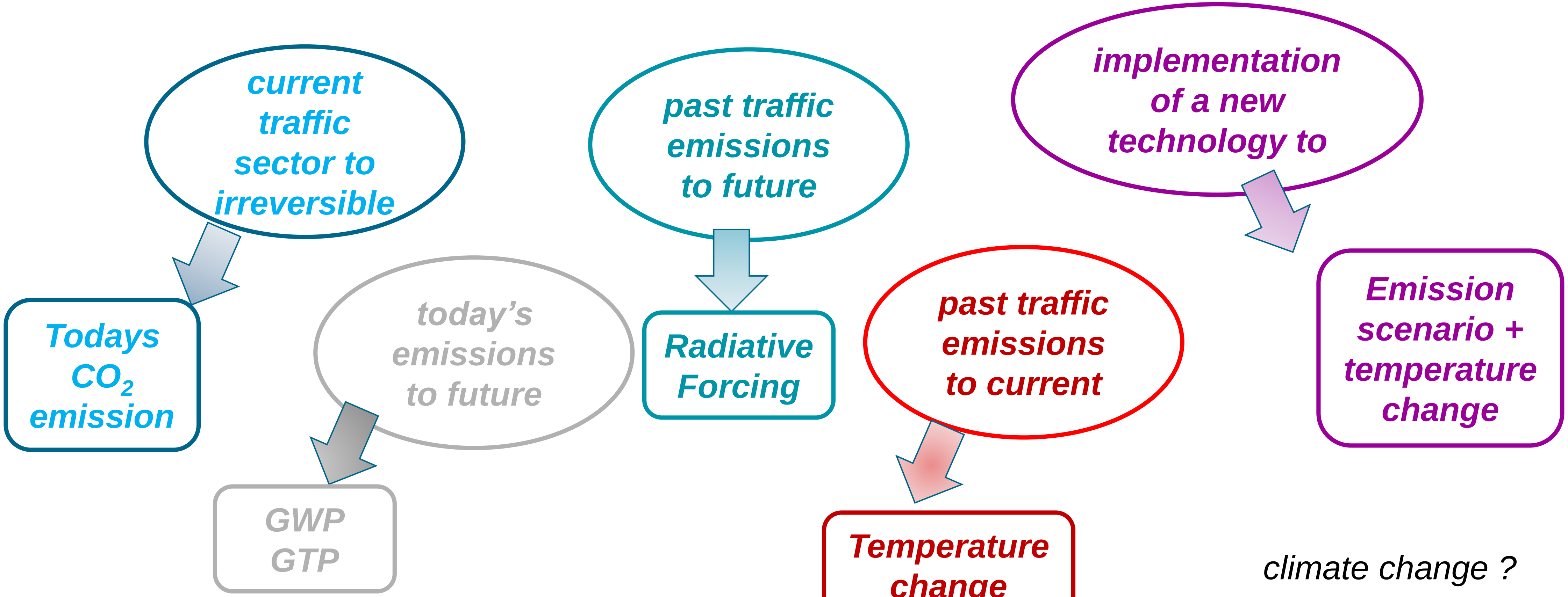
$$\Delta T_{spec}(t) \longrightarrow GTP = \frac{\Delta T_{spec}(t)}{\Delta T_{CO_2}(t)} \longrightarrow ATR = \frac{1}{H}\int_0^H \Delta T_{spec}(t)$$





Climate change questions: „What is the climate impact of traffic?“

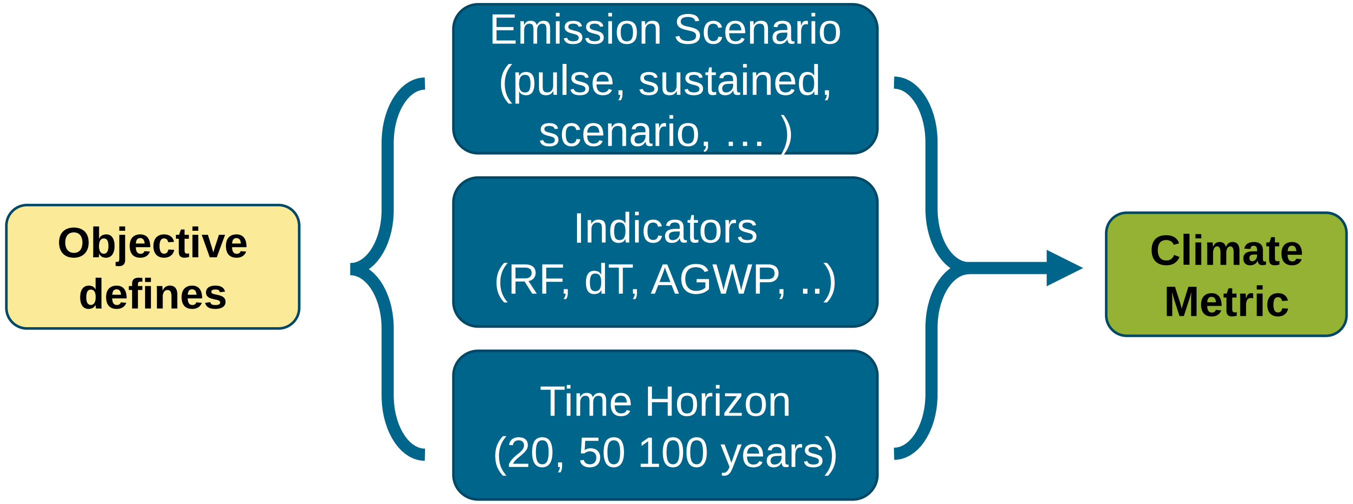
How large is the contribution of the



climate change ?

Climate metrics

- **Metric** = quantitative measure of climate effects
- **Purpose** = Evaluation of CO_2 and non-CO_2 effects with various lifetimes
- **Weights** = different metrics weight CO_2 and non-CO_2 effects differently
- **Specific** = Choice depends on objective! Not all Climate Metrics suit all purposes!
- **Input** = always the calculation of radiative forcing (RAD) + efficacies



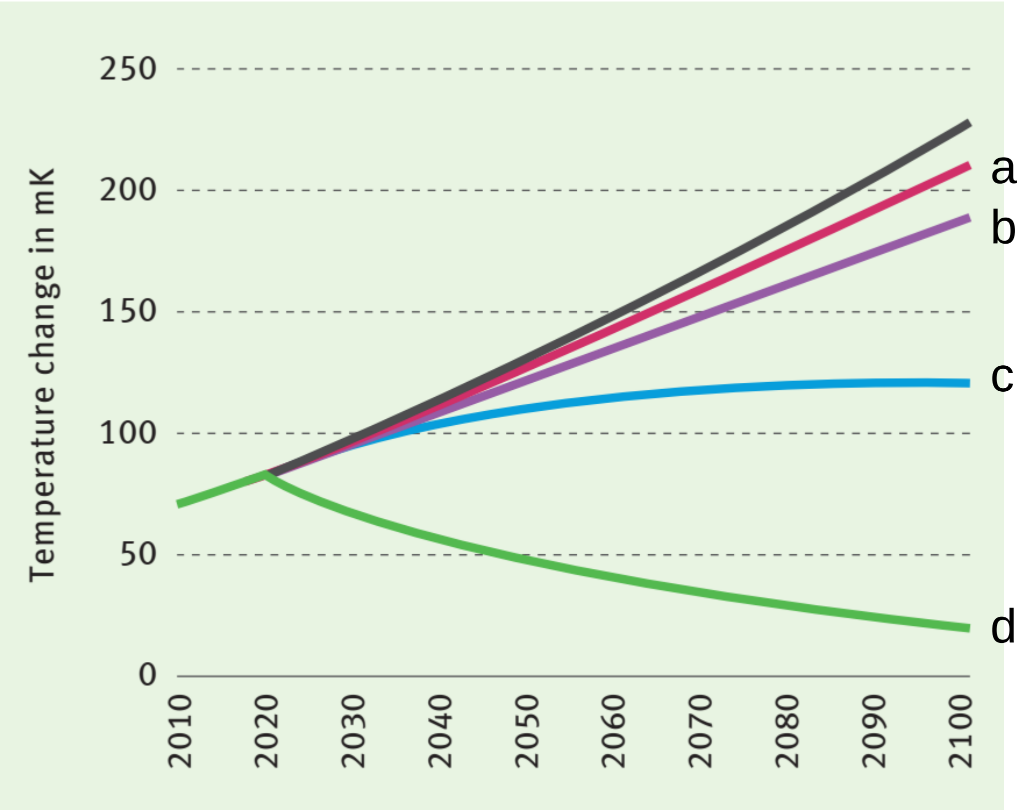
Question:

https://pingo.coactum.de/054568

In the figure the temporal development of global aviation is shown for different future scenarios. The black one is a business as usual scenario.

- Which development would we receive if we assume CO_2 neutral growth?

a b c d



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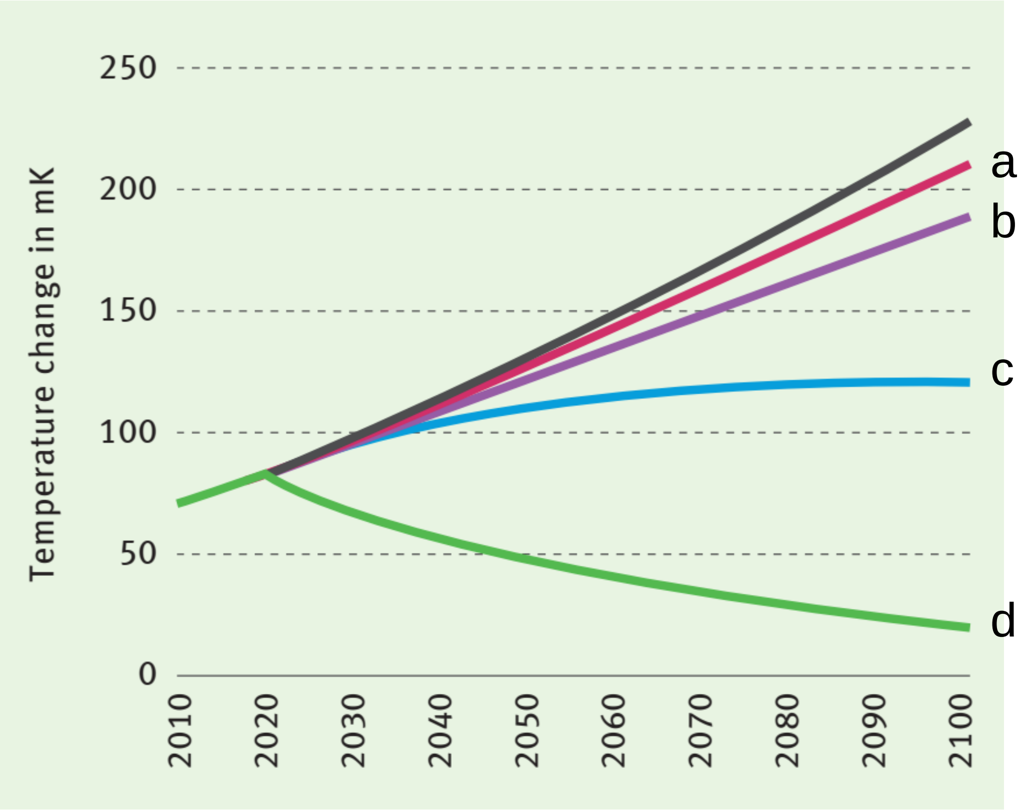

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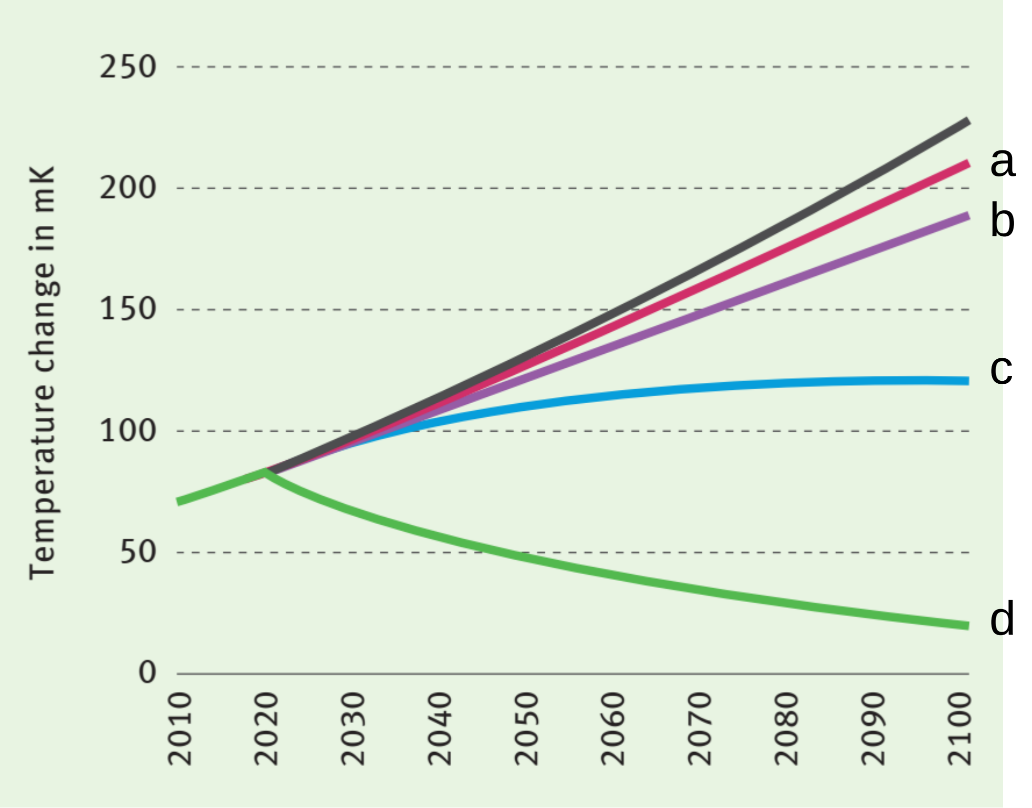

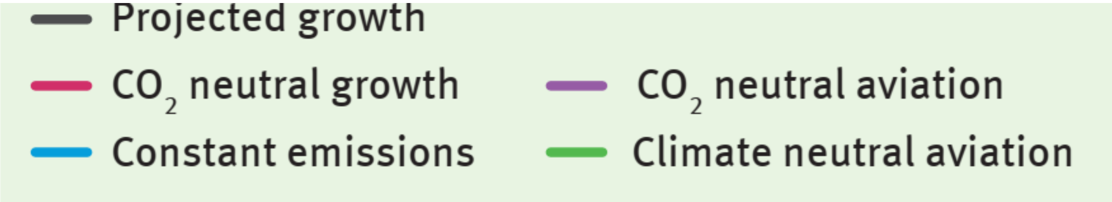

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Question: Which climate metric could be used to analyse whether aviation is inline with Paris agreement?

- Scenario emission, RF, 2100
- Pulse emission, ATR, 100 years
- Scenario emission, Temperature change, 2100

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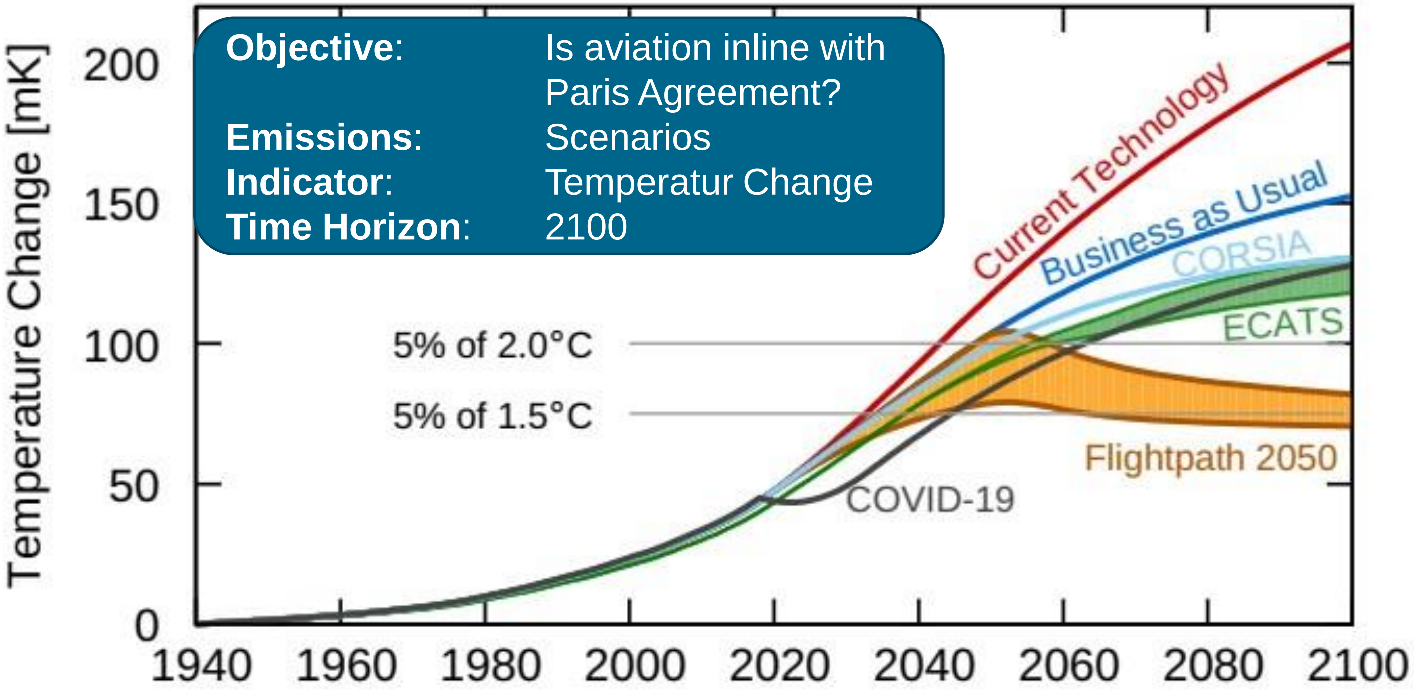


Grewe, Matthes, Dahlmann et al. (2021)

Source: pexels.com

SUMMARY

Summary

Aviation climate effects

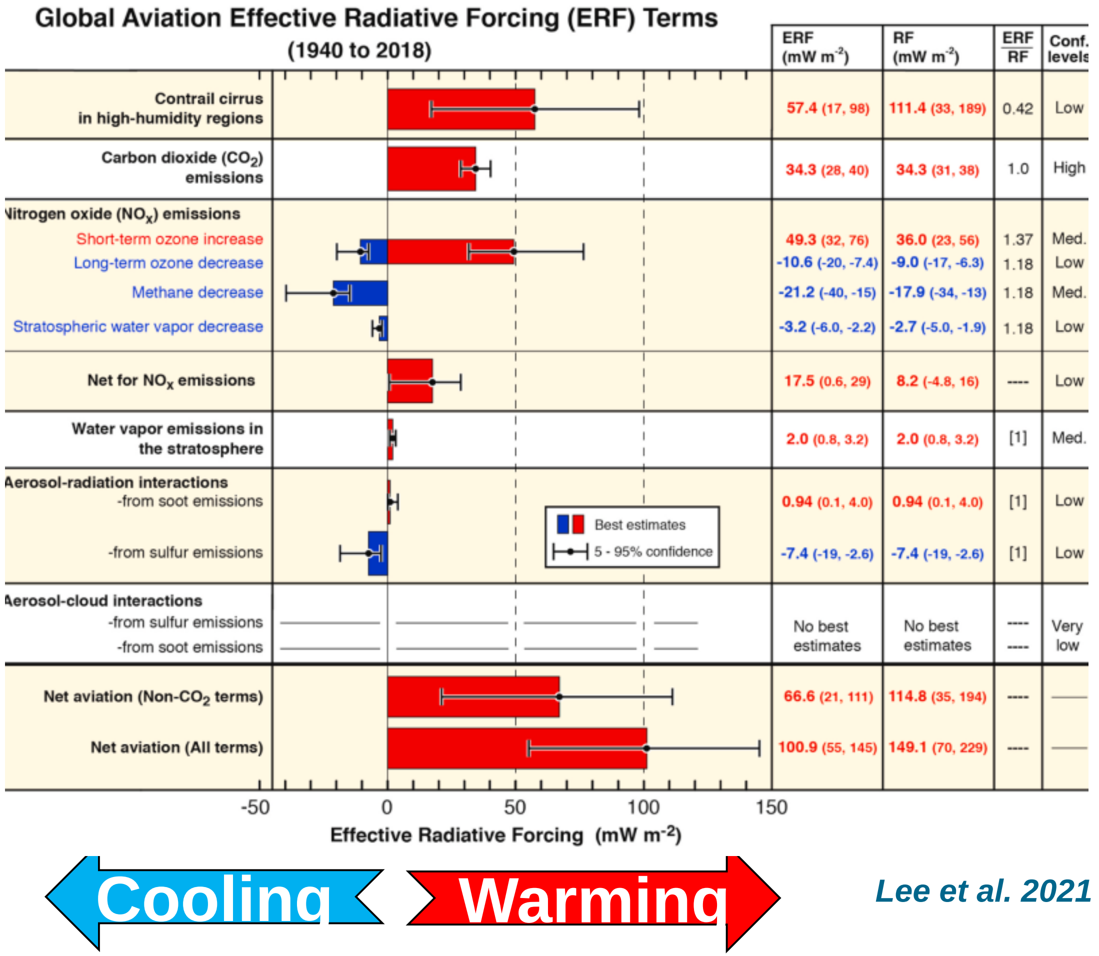
- **Non-CO_2 effects** are important
- Climate effects of **non-CO_2 effects depend** on emission location, meteorological conditions and background concentrations

⇨ Climate effects are **not proportional** to amount of non-CO_2 emissions

Counteracting effects causing trade-offs

- Very different properties of species

- Not all Climate Metrics suit all purposes! Purspose defines choice of metric



Lee et al. 2021

THANK YOU FOR YOUR ATTENTION!

QUESTIONS?

Source: pexels.com