

More than CO₂

Robert Sausen

Institut für Physik der Atmosphäre
Deutsches Zentrum für Luft- und Raumfahrt
Oberpfaffenhofen

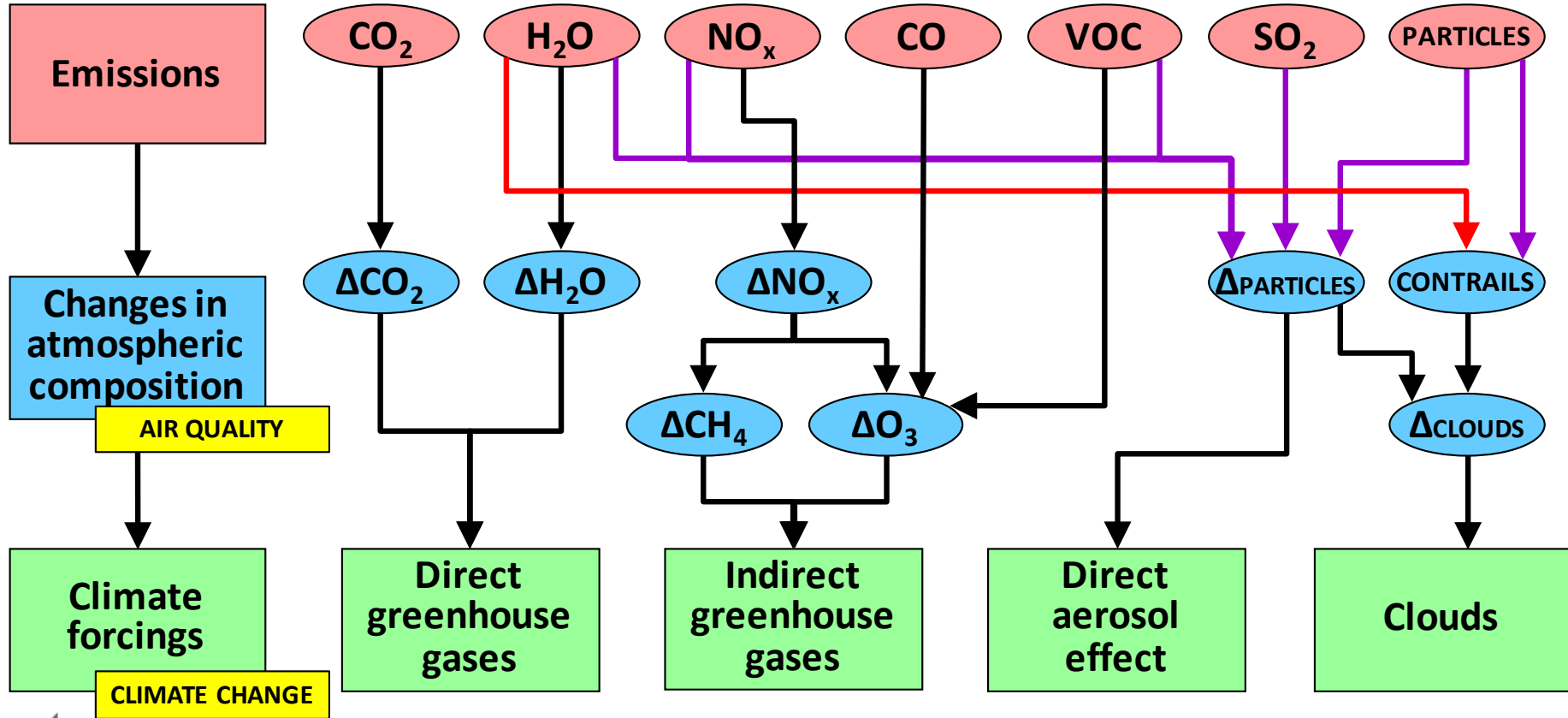
EUROCONTROL Stakeholder Forum on aviation's impact on non-CO₂ emissions
27 April 2021



Knowledge for Tomorrow



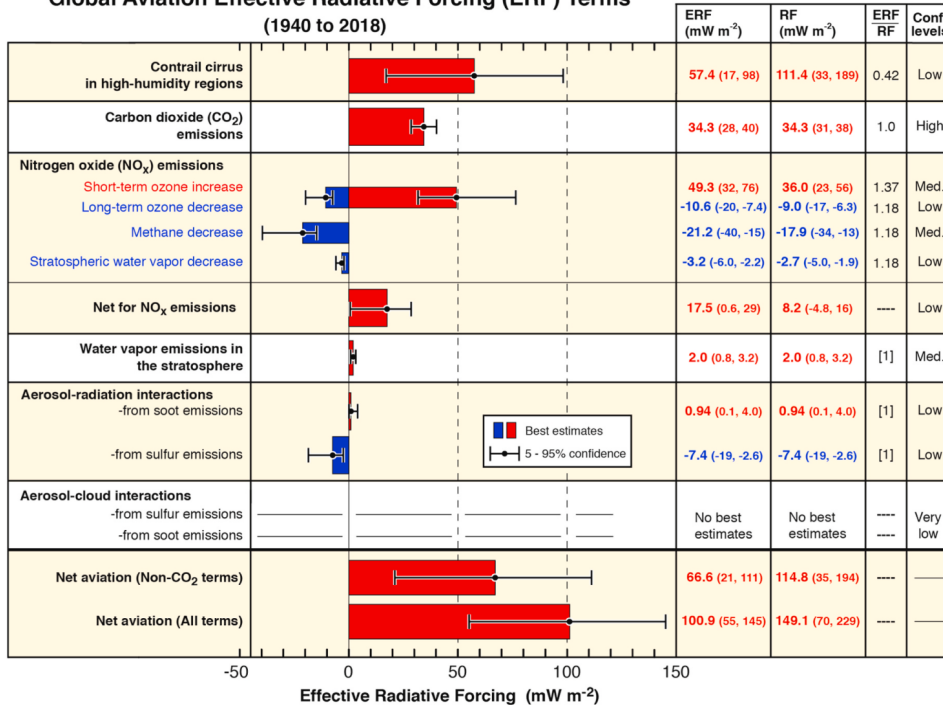
Atmospheric effects of emissions from the aviation sector



Effective radiative forcing (ERF)

$$\Delta T = \lambda \text{ ERF}$$

Global Aviation Effective Radiative Forcing (ERF) Terms
(1940 to 2018)



Lee et al., 2021

➤ The non-CO₂ effects contribute at least 2/3 to the total aviation ERF.

➤ Non-CO₂ effects also occur if alternative fuels are used, in particular H₂.

➤ The magnitude of the non-CO₂ effects depends on location and time of the emissions.



How can we mitigate the climate impact of aviation?

Focus more on emissions:

- Reduction of the specific emissions (e.g., alternative fuels, hydrogen/electric powered aircraft)
- Reduction of the absolute emissions

Focus more on impact of emissions:

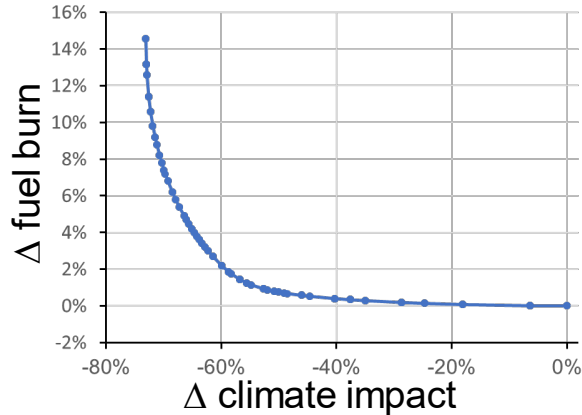
- Climate optimized aircraft (e.g., for flights at lower cruise altitude and lower Mach number)
- Eco-efficient flight trajectories (requires adapted ATM)



Eco-efficient flight trajectories

The magnitude of the non-CO₂ effects significantly differs from flight to flight and, hence, **cannot** simply be accounted for by a **constant factor**. Hence, a simple multiplier is a wrong method.

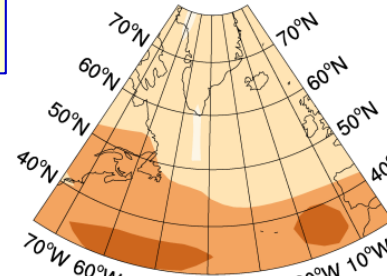
Preferably fly at locations and altitudes, where the climate impact is particularly low.



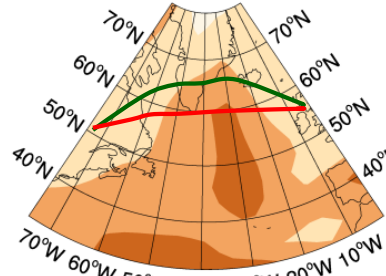
based on Matthes et al., 2020

Climate change functions
(climate cost functions) [10^{-14} K / kg(N)]

weather 1



weather 4



Routes illustrative

Frömming et al., 2021

The total climate impact (CO₂ and non-CO₂ effects) is strongly reduced at only small additional fuel burn.

Trial now (MUAC/DLR) and demonstration of the methods until 2024 with the planned German LuFo project D-KULT (Consortium with major industrial partners)



Final remarks

- Aviation significantly contributes to global warming, and the aviation share has been growing.
- The non-CO₂ effects (from NO_x, contrail cirrus, particles) are particularly large for the aviation sector. Comparing non-CO₂ effects and CO₂ for strategic decisions requires suitable metrics. The knowledge about the aviation non-CO₂ effects has been increased substantially.
- Some of the non-CO₂ effects are warming, others are cooling. The uncertainty remains high, in particular for the indirect aerosol effects. This is not a sufficient reason for not to act. And part of the uncertainty is due to the every-day weather variability.
- The life time of the non-CO₂ effects is shorter than that of CO₂, but the forcing is larger.
- The climate impact of aviation can be mitigated by
 - reduction of specific emissions,
 - alternative fuels,
 - eco-efficient flight trajectories (e.g., climate-optimal trajectories, climate restricted areas, climate charged areas)

→ ...

