



Aviation non-CO₂ emissions

25 years of EU-funded activities and what's next for research and policy?

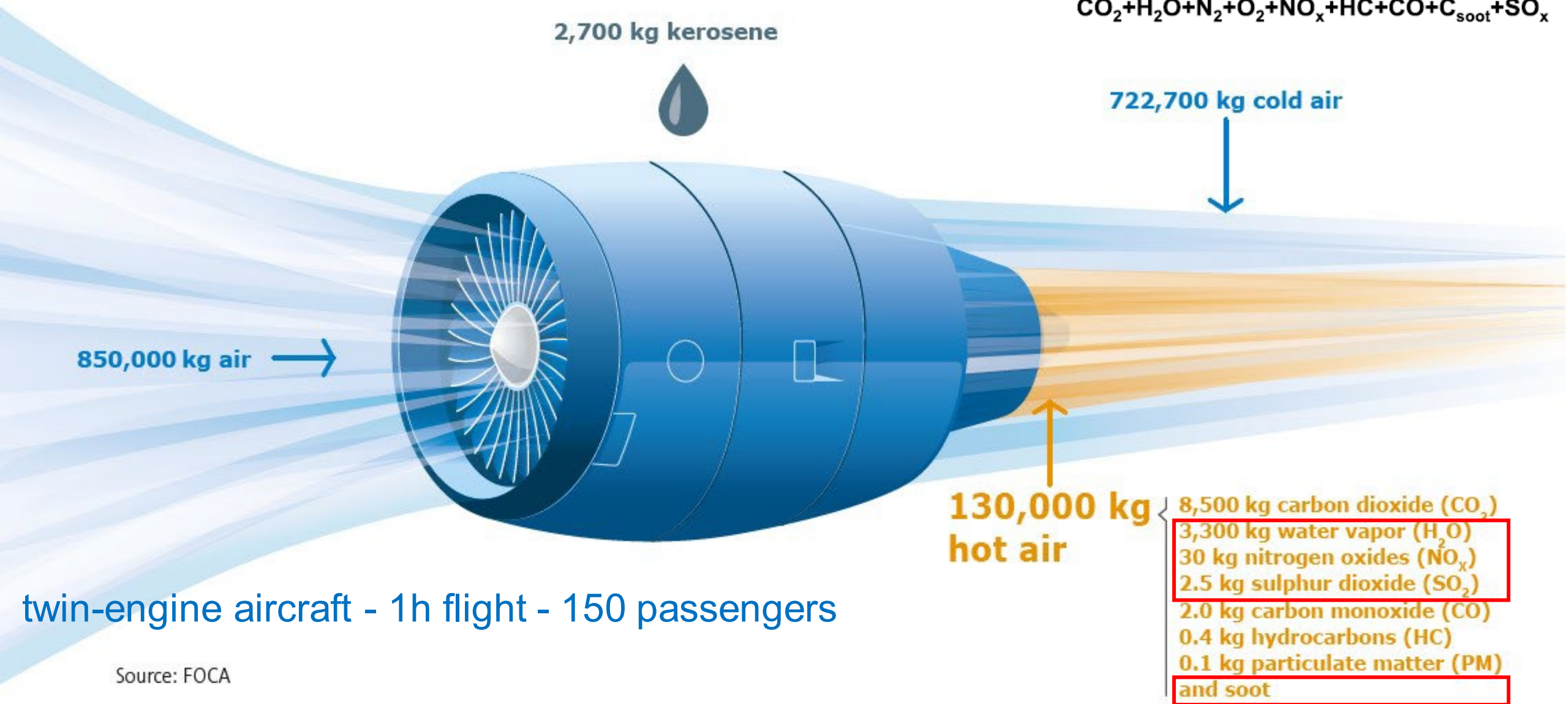
Michael Kyriakopoulos, RTD.C3

7-8 November 2023

What comes out today?

Ideal Combustion:
 $\text{CO}_2 + \text{H}_2\text{O} + \text{N}_2 + \text{O}_2 + \text{SO}_2$

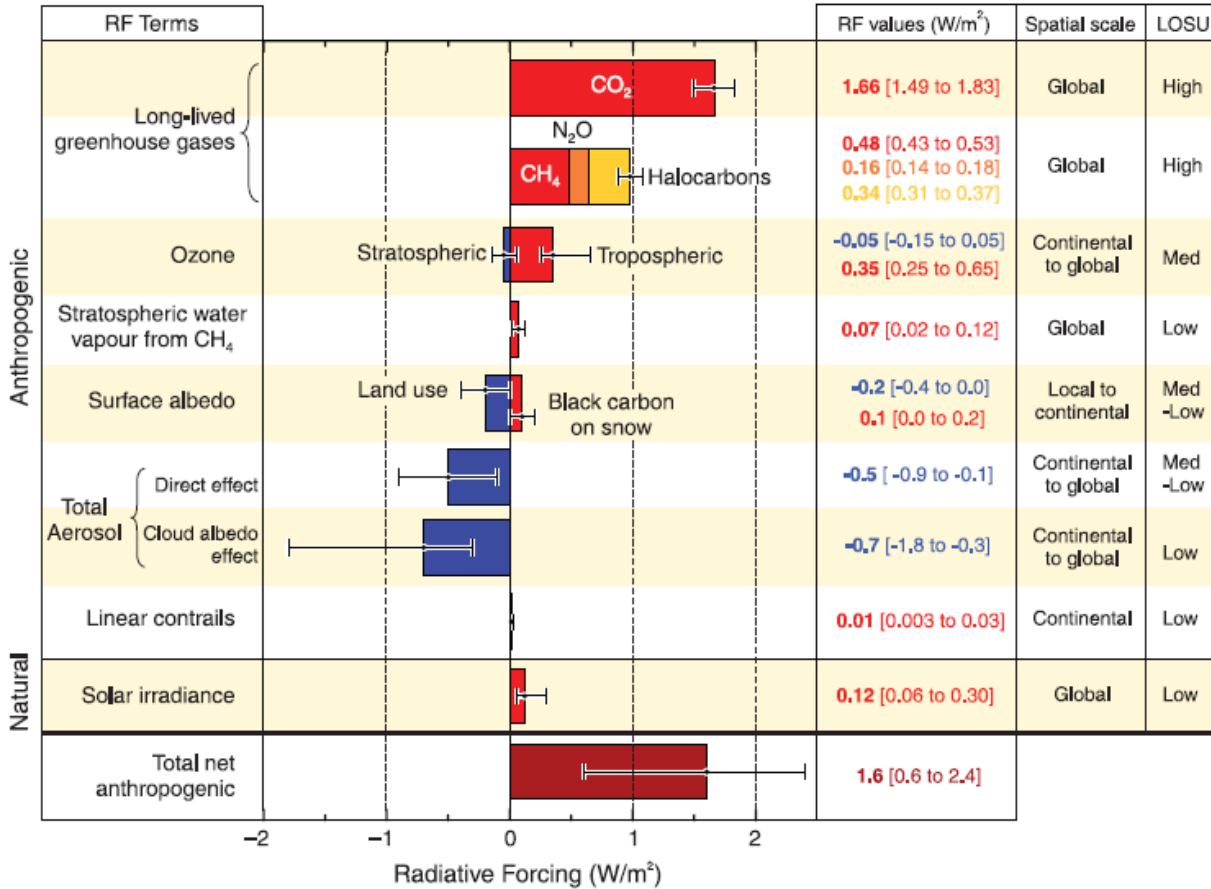
Real Combustion:
 $\text{CO}_2 + \text{H}_2\text{O} + \text{N}_2 + \text{O}_2 + \text{NO}_x + \text{HC} + \text{CO} + \text{C}_{\text{soot}} + \text{SO}_x$



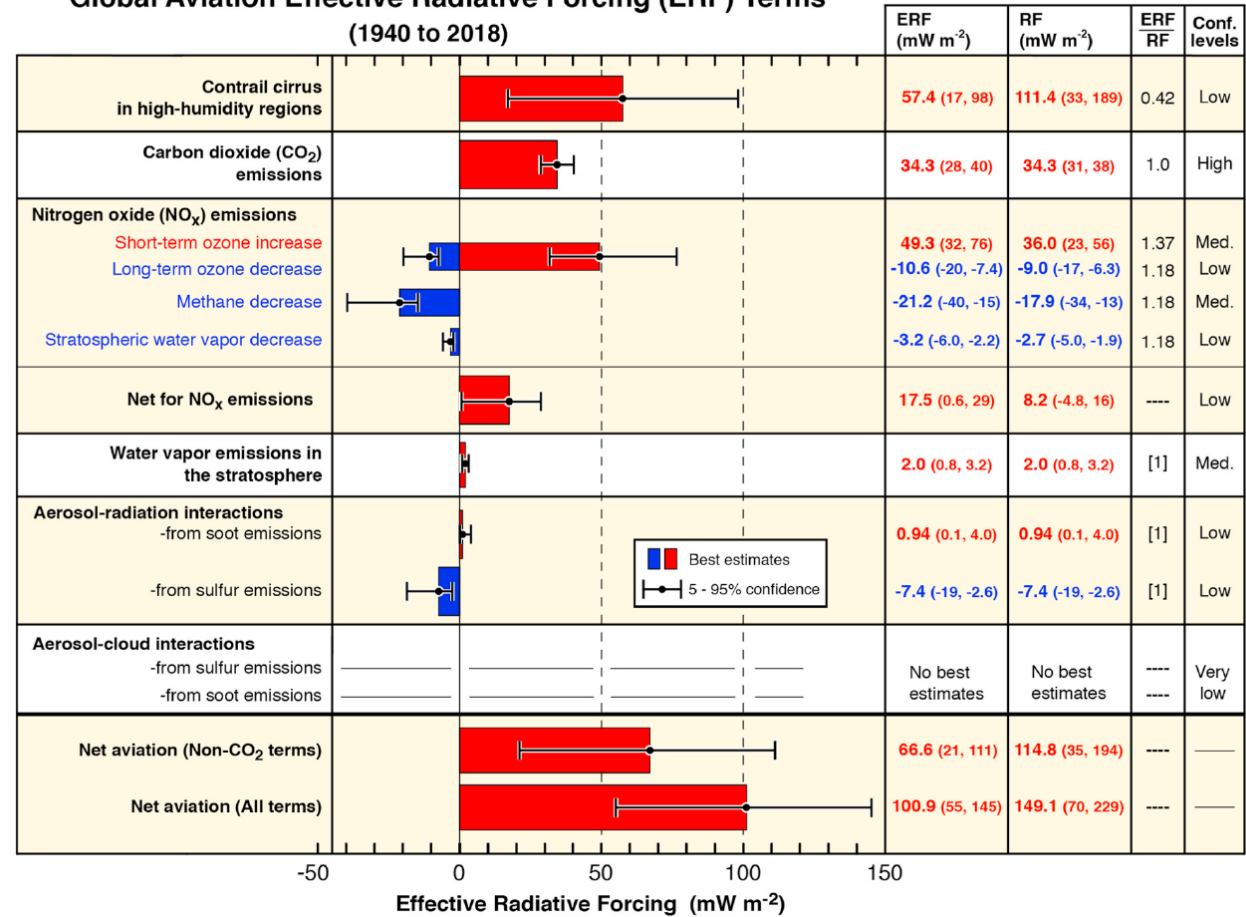
twin-engine aircraft - 1h flight - 150 passengers

Total Anthropogenic and Global Aviation RF

Radiative forcing components



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



What will come out from H2-powered aviation?



Exhibit 4

Comparison of climate impact from H₂ propulsion and synfuel

Compared to kerosene-powered aircraft, timeframe until 2100

Ongoing scientific debate about full climate impact, in particular:

- Contrail/cirrus formation
- Aggregate measure

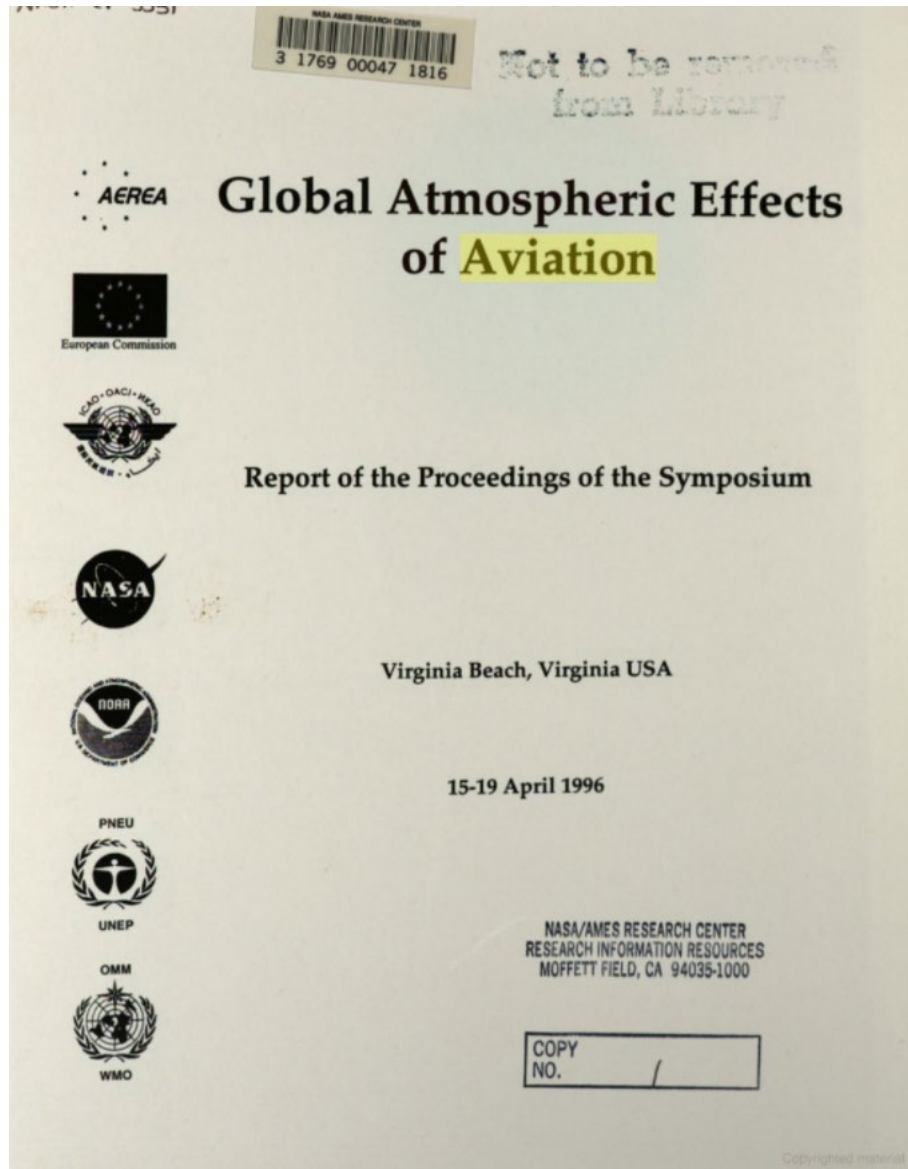
Total climate impact could be 2 to 4 times compared to CO₂ emissions alone

Change of in-flight emissions and emission related effects¹

	Direct CO ₂	NO _x	Water vapor ²	Contrails, cirrus	Climate impact reduction potential ⁴
Synfuel	-0% -100% (Net) ³	-0%	-0%	-10-40%	-30-60% ³
Hydrogen turbine	-100%	-50-80%	+150%	-30-50%	-50-75%
Hydrogen fuel cell	-100%	-100%	+150%	-60-80%	-75-90%

1. Assuming decarbonized production and transportation of fuels in 2050
2. 10 times lower climate impact than from CO₂ emissions
3. Net CO₂ neutral if produced with CO₂ captured from the air
4. Measured in CO₂ equivalent compared to full climate impact of kerosene-powered aviation

Global Atmospheric effects of Aviation



European Commission

Air pollution research report 83

European Conference on Aviation, Atmosphere and Climate (AAC)

Proceedings of an International Conference

Friedrichshafen, Germany, 30 June to 3 July 2003

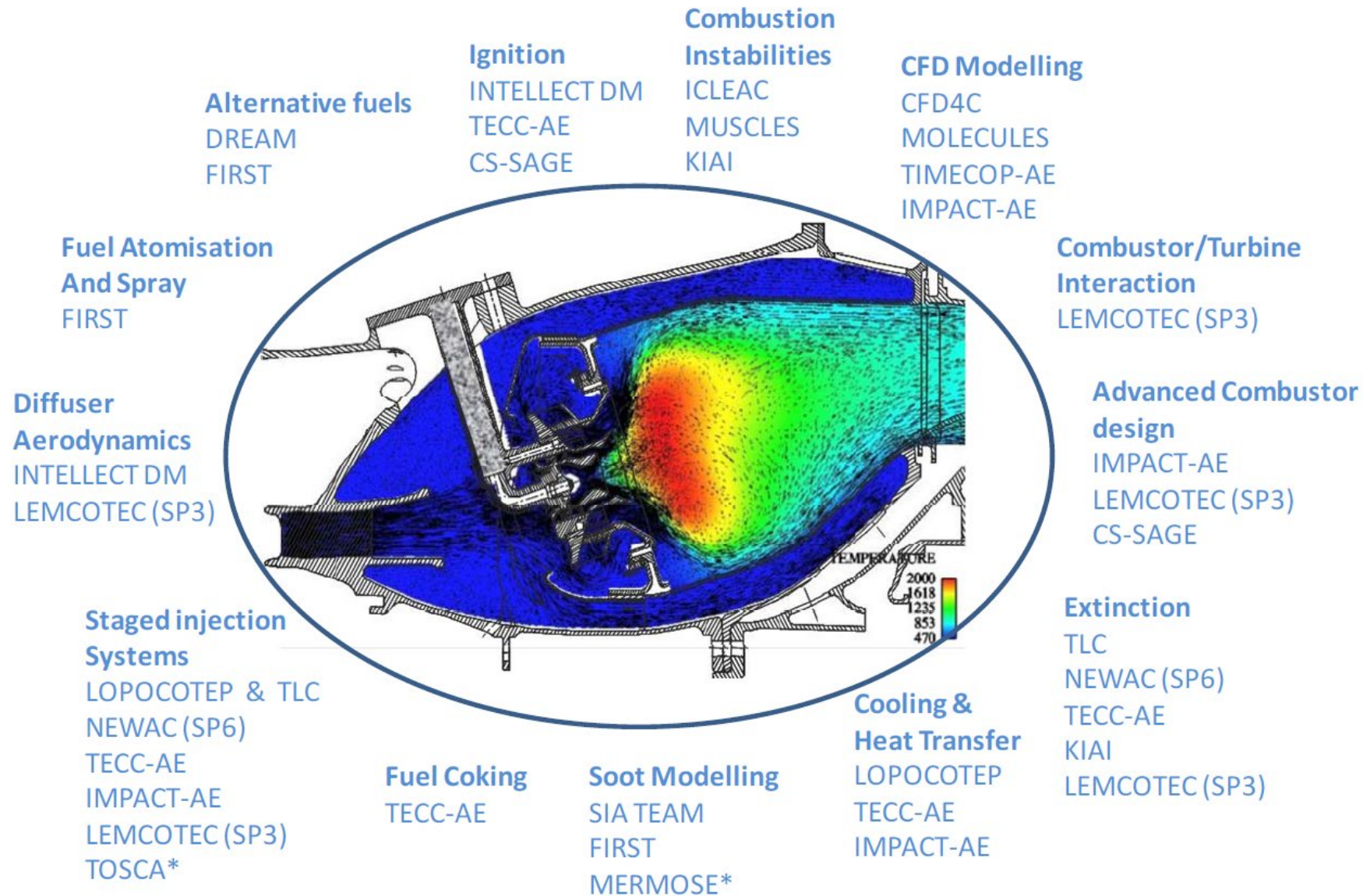


Edited by

Robert Sausen, Christine Fichter and Georgios Amanatidis



Reducing NOx – Combustion technologies



FP7-REACT4C and SESAR-ATM4E - lighthouse projects



M36-2nd Periodic Report, V1.3
July 2011 – Dec 2012



REACT4C
ACP8-GA-2009-233772

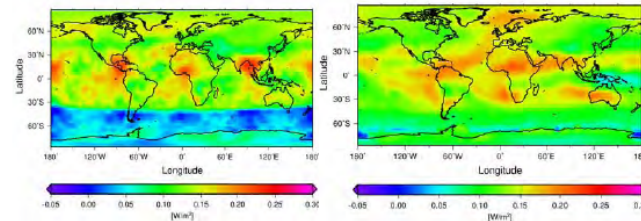


Figure 2.2: January mean net RF at the tropopause for 1% additional contrail cover at ~200 hPa for EMAC (left) and ECHAM4 (right) from benchmark test.

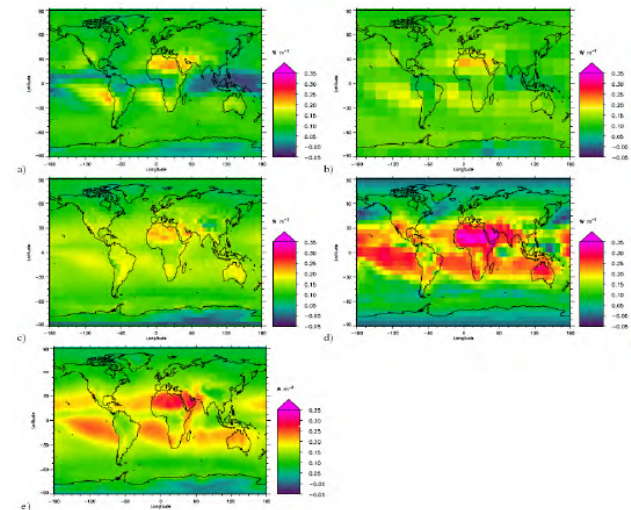


Figure 2.3: Radiation benchmark test: for comparison with EMAC results (Figure 2.2) values from atmospheric models included in Myhre et al., 2009, MetZ.: Annual mean net radiative forcing at the top of the atmosphere for 1% contrail cover UIO BBM a), UoR FU b), UW FU c), CNRM d), UoL E-S e).

6. Water vapour emissions implemented with transport and rain out, RF calculation parameterised according to Grewe and Stenke, 2008.
7. Model documentation extended for publication in Geoscientific Model Development.
8. One weather situation simulated and analysed and results transferred to CICERO.



REACT4C
ACP8-GA-2009-233772



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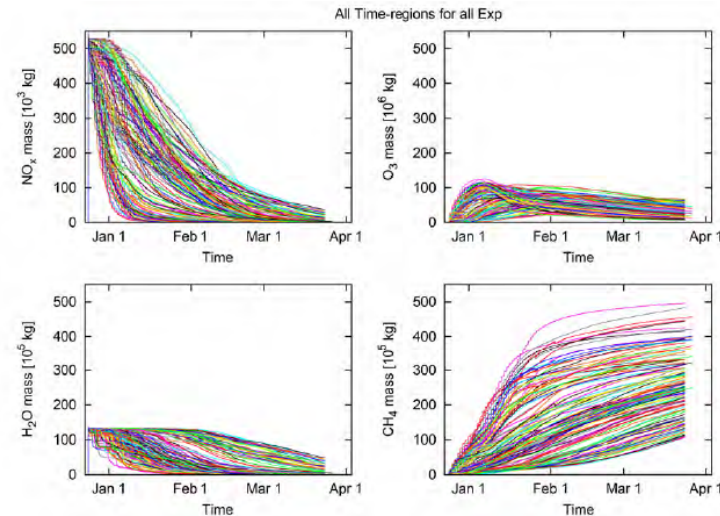


Figure 2.4: Changes in the mass of NO_x , O_3 , H_2O and CH_4 for a normalized emission at 168 different emission points for the winter weather pattern "strong zonal". The variability among the results for different emission locations is determined by the meteorology, leading to different transport pathways, and different hydrological and chemical processes. Based here on maps of radiative forcing were produced and transferred to CICERO for further pressing.

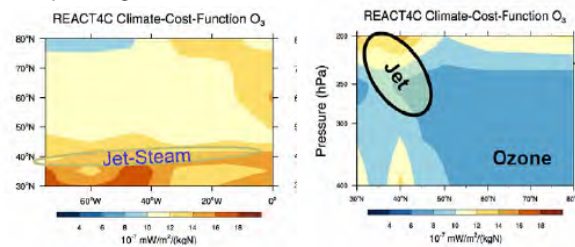


Figure 2.5: Specific radiative forcing ($\text{mW}/\text{m}^2/\text{kgN}$).

9. All other weather pattern identified in EMAC and matched to real dates in ERA-Interim.
10. Simulations for all weather patterns prepared.
11. CICERO: The cost function prototype was modified to cover a larger area, and also split AIC into wind directions.
12. CICERO: Climate-Cost-functions for the first weather situation was calculated and transferred to Eurocontrol.



Workshop on Aviation non-CO₂ emissions

13-14 December 2023

European Commission, Brussels
BREY Auditorium - Avenue d'Auderghem 45

- To provide an overview of the **state-of-play of aviation non-CO₂ impacts**;
- To listen to all relevant stakeholders, identify research and policy gaps, and gather recommendations, that have the **potential to actually reduce the aviation non-CO₂ impacts**, mainly via new technologies and optimised operations, in the short- and medium-term.
- To contribute to a quantified and scientifically-agreed **roadmap** towards minimising all non-CO₂ aviation impacts towards 2050 (and 2070), considering all possible measures (i.e. new technologies, optimised operations, new fuel options, and market-based measures) in combination as well as the trade-off between CO₂ and non-CO₂ emissions. The workshop is confined primarily to the climate effects of non-CO₂ aviation emissions, while Local Air Quality (and noise) will be the subject of an upcoming workshop in Q3 2024.
- To **communicate the findings** of the workshop and contribute towards clearing the fog that surrounds the issue, for the benefit of aviation and the climate.

Thank you for your attention!



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