Climate Impact assessment of aircraft engine technology

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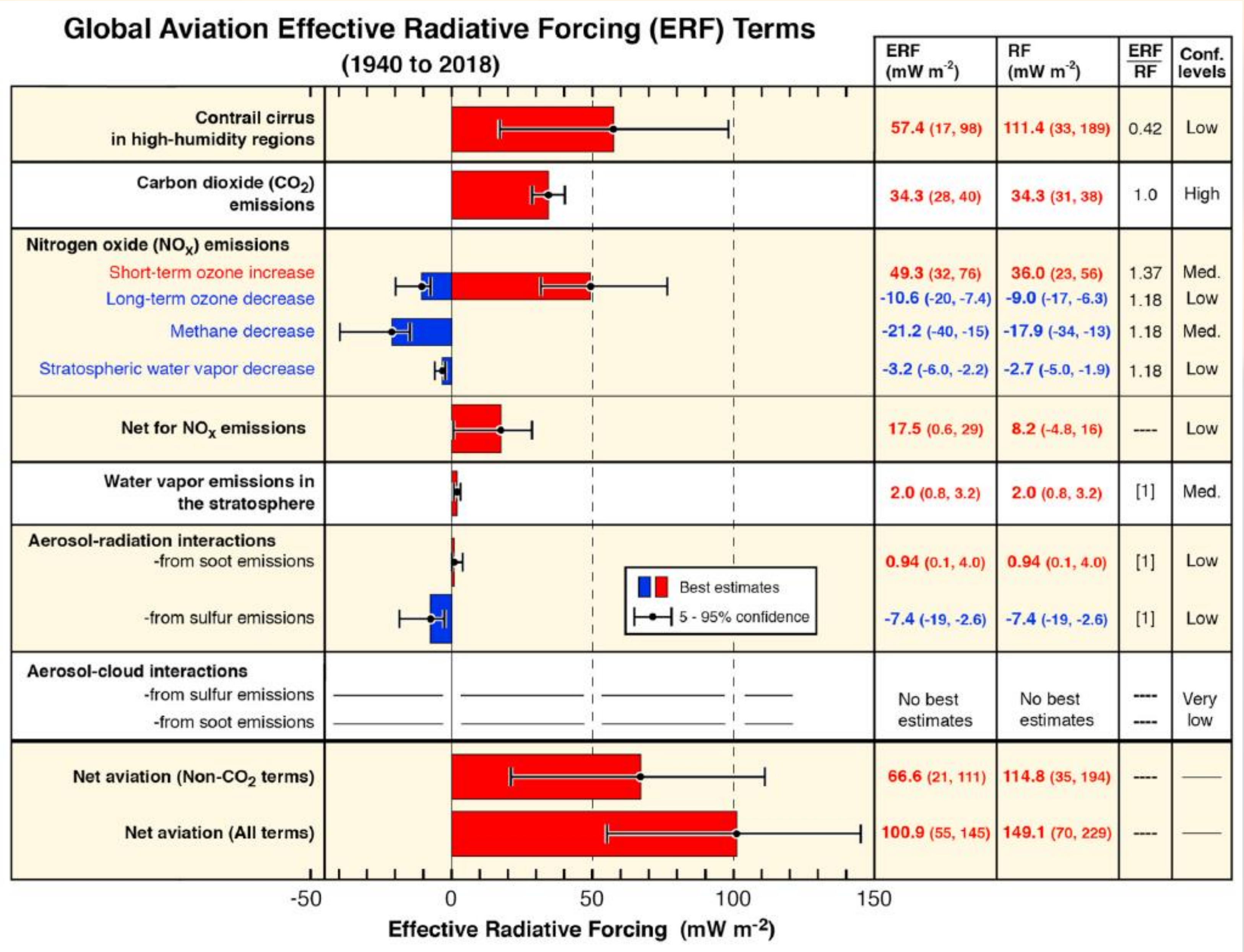
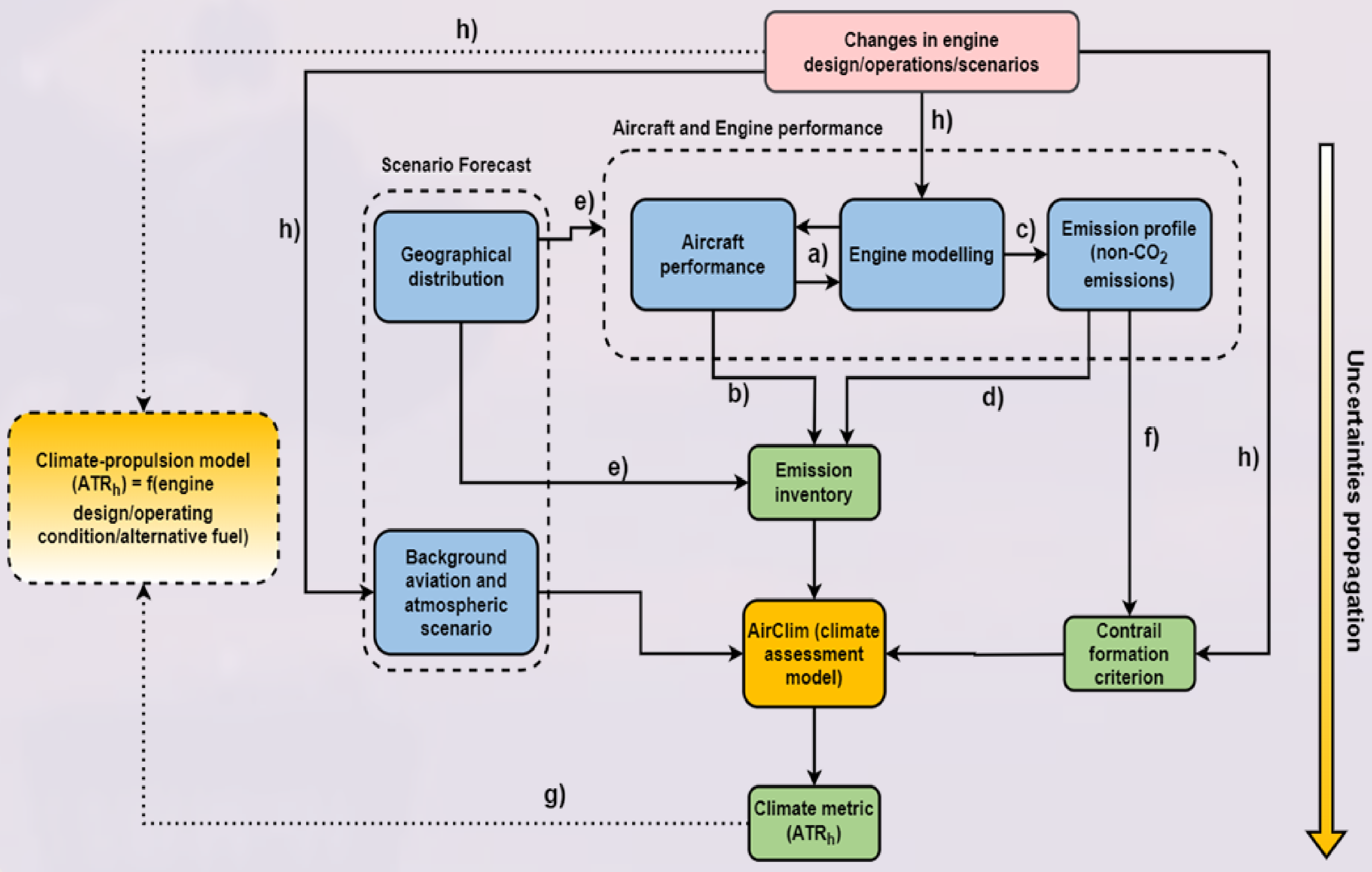
BACKGROUND



Aviation emissions & their associated Radiative Forcing from 1940 to 2018. [1]

- Aircraft emissions contribute ~3.5% of global anthropogenic Effective Radiative Forcing (ERF).
- Around two-thirds is due to the non-CO_2 emissions & their related effects.
- Aircraft engine design trends tend to increase the non-CO_2 emissions.
- The total climate impact must be considered for future engine designs.

METHODOLOGY



a) Aircraft-engine design iteration
b) Aircraft performance (Fuel, ROCD)
c) Engine thdy. data
d) non-CO_2 emissions (NO_x, nvPM)
e) Flight network
f) H_2O, nvPM emissions
g) ATR_h
h) Design/operations/scenario changes

Ph.D. RESEARCH FOCUS

To develop a climate-propulsion model that can estimate the climate impact of an aircraft engine design, & which can be integrated within the engine design routine.

- Airbus A320 + CFM56-5B engine
- ~150 city pairs
- Cruise altitude= 10.668 km, Mach no. = 0.78

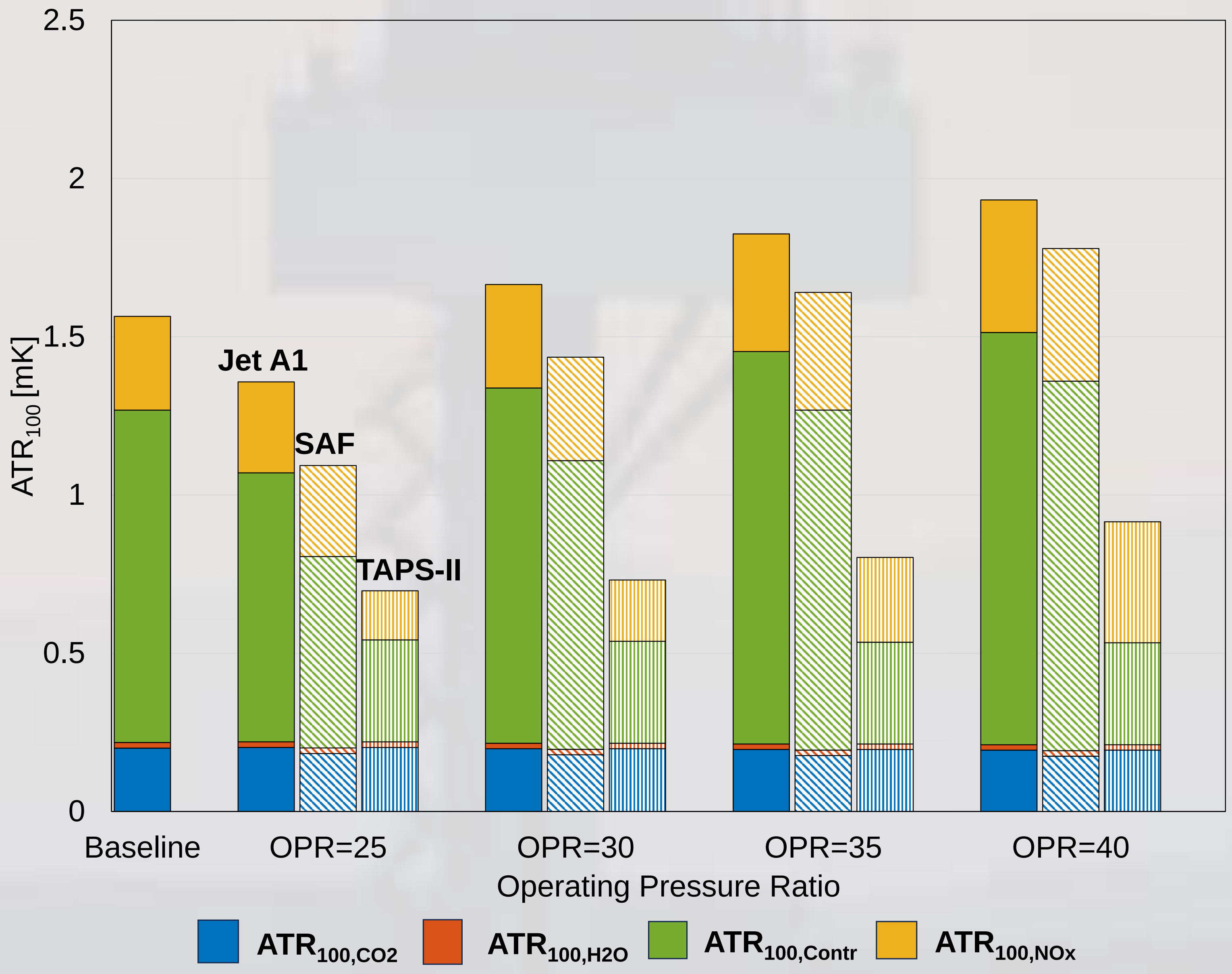
- Aviation scenario: *CurTec* (technology freeze in 2012)
- Background CH_4 & CO_2 scenario: IPCC SSP2-4.5

- Engine performance modelling: Gas Turbine Simulation Program (GSP) [2]
- Climate assessment: AirClim [3]
- In-house emission modelling

- Design parameter: Overall Pressure Ratio (OPR)
- Fuel: Jet A-1 v/s SAF HEFA (Sustainable Aviation Fuel; Hydrotreated Esters & Fatty Acids; Soy feedstock)
- Combustor: RQL (rich burn) v/s TAPS-II (lean burn)

- Metric: Average Temperature Response over 100 years (ATR_{100})

KEY RESULT



Climate response sensitivity w.r.t OPR, SAF fuel, & lean combustion application [4-5]

- Increasing the OPR reduces CO_2 impact but leads to higher non-CO_2 impact.
- CO_2 impact reduction does not compensate non-CO_2 impact (NO_x & contrails) increase enough.
- SAF reduces both CO_2 & nvPM emissions, thus the associated CO_2 & contrail impacts.
- Lean-burn TAPS-II reduces NO_x emissions & its subsequent climate impact.

References:

[1] Lee, D. S.; Fahey, D. W.; Skowron, A.; Allen, M. R.; Burkhardt, U.; Chen, Q.; Doherty, S. J.; Freeman, S.; Forster, P. M.; Fuglestvedt, J. The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. *Atmos Environ* ***2021, 244, 117834.***

[2] Visser, W. P. J.; Broomhead, M. J. GSP, a Generic Object-Oriented Gas Turbine Simulation Environment. In *ASME Turbo Expo 2000: Power for Land, Sea, and Air, 2000; V001T01A002, Vol. Volume 1: Aircraft Engine; Marine; Turbomachinery; Microturbines and Small Turbomachinery. DOI: 10.1115/2000-gt-0002.*

[3] Grewe, V.; Stenke, A. AirClim: an efficient tool for climate evaluation of aircraft technology. *Atmos Chem Phys* ***2008, 8 (16), 4621-4639. DOI: DOI 10.5194/acp-8-4621-2008.***

[4] Saluja, H. S.; Yin, F.; Gangoli Rao, A.; Grewe, V. Effect of Engine Design Parameters on the Climate Impact of Aircraft: A Case Study Based on Short-Medium Range Mission. Aerospace 2023, 10 (12), 1004.

[5] Saluja, H. S.; Yin, F.; Gangoli Rao, A. Investigating the influence of turbofan engine design on - climate for a short-to-medium-range flight network. In Aerospace Europe Conference 2023, Lausanne, Switzerland; 2023.

FUTURE WORK

- Generalized analysis
- (Future) Engine design vs climate impact → sensitivity analysis
- Climate Response Function development
- Uncertainty analysis → quantitative significance

This work is carried out within:
1. “Fly Green: Choices at crossroads”, NWO VENI Project 17367 (Nov. 2019- Dec. 2023)
2. “MInimum enviroNmental IMpact ultra-efficient cores for Aircraft propuLsion”, MINIMAL, GAN 101056863, Horizon Europe, European Commission, (Sept. 2022 – Aug. 2026)