How to efficiently design aircraft with minimum climate impact?

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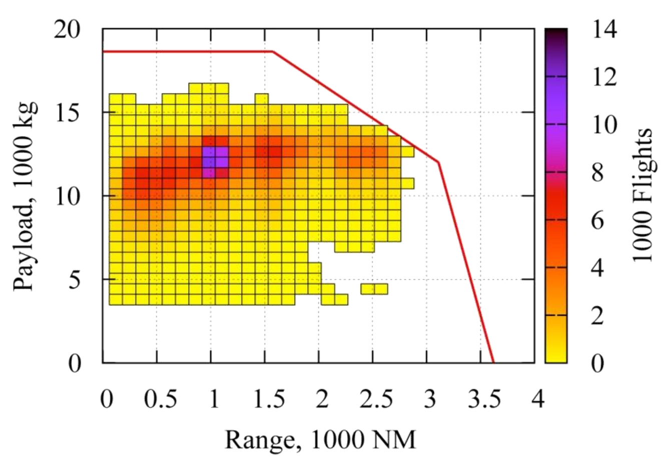
GLOWOPT

Abstract

- **Aircraft emissions** responsible for about 5% of global anthropogenic radiative forcing, including **CO_2 and non-CO_2 effects** (NO_X, H_2O, Contrails…).
- Aviation stakeholders need to **rethink the way** aircraft are designed and operated to minimize global warming.
- Analysis of aviation climate impact requires consideration of interaction between **aircraft, routing and trajectories, atmospheric physics and climate.**
- **Non-CO_2 effects** are highly dependent on atmospheric state and sensitive to **location and time of emission.**
- Evaluating the climate impact of a new aircraft design normally requires a **complex simulation and analysis environment**.
- European Clean Sky 2 project **"Global Warming Optimized Aircraft Design (GLOWOPT)"** is aimed at developing innovative **Climate Functions for Aircraft Design (CFAD)** using an interdisciplinary approach combining the expertise of aircraft design, operations, atmospheric physics and climate.

Motivation

- Aircraft design optimization studies typically use **fuel burnt, MTOW or DOC** as objective function.
- **More than 50%** of the aviation impact on climate arises from non-CO_2 effects.
- Most routes have a mission range considerably **below** the maximum mission range
- This results in **oversized aircraft** and more emissions (more global warming impact) on such missions.
- Designing aircraft for minimum climate impact requires a climate function which is **sensitive** to aircraft/engine design parameters and operational parameters.

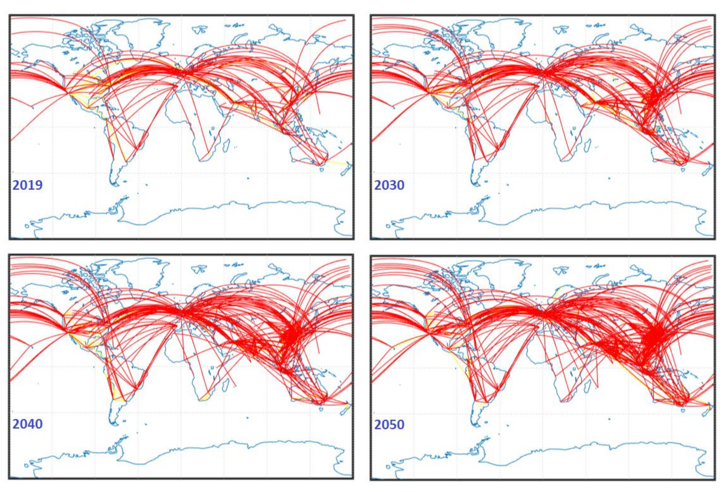


Payload-range capabilities and actual operating regime on an Airbus A320 aircraft [1]

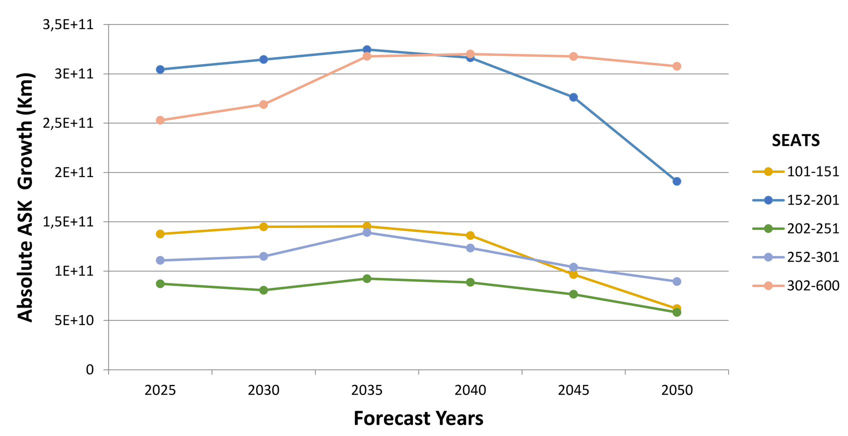
Route Network

Coupling aircraft environmental performance with aircraft design process based on analysis of aircraft fleet and global route structure:

- **4 layer philosophy** for air traffic forecast [2]
- Overview on required transport capacities.
- **Identifying relevant design requirements** from range, flight frequency, aircraft size and infrastructure constraints.



Forecasted global air traffic growth of seat categories 252-301 and 302-600, until 2050



Available seat kilometer growth vs. forecasted years for aircraft categories

Selecting a **relevant market segment** for the next generation aircraft design:

- Increasing air traffic demand leads to **increased** proportion of **wide body aircraft** in the future.
- Characterizing **representative route network** for the selected market segment to calculate CFADs

References

1. M. Husemann, K. Schaefer and E. Stumpf, "Flexibility within flight operations as an evaluation criterion for preliminary aircraft design," Journal of Air Transport Management, vol. 71, pp. 201-214, 2018
2. R. Ghosh, K. Kölker and I. Terekhov, "Future passenger air traffic modelling: A theoretical concept to integrate quality of travel, cost of travel and capacity constraints" In proceedings of the 19th World Conference of the Air Transport Research Society (ATRS), Singapore, 2-4 July 2015.
3. V. Grewe and A. Stenke, "AirClim: an efficient climate impact assessment tool," vol. 8, pp. 4621-4639, 2008

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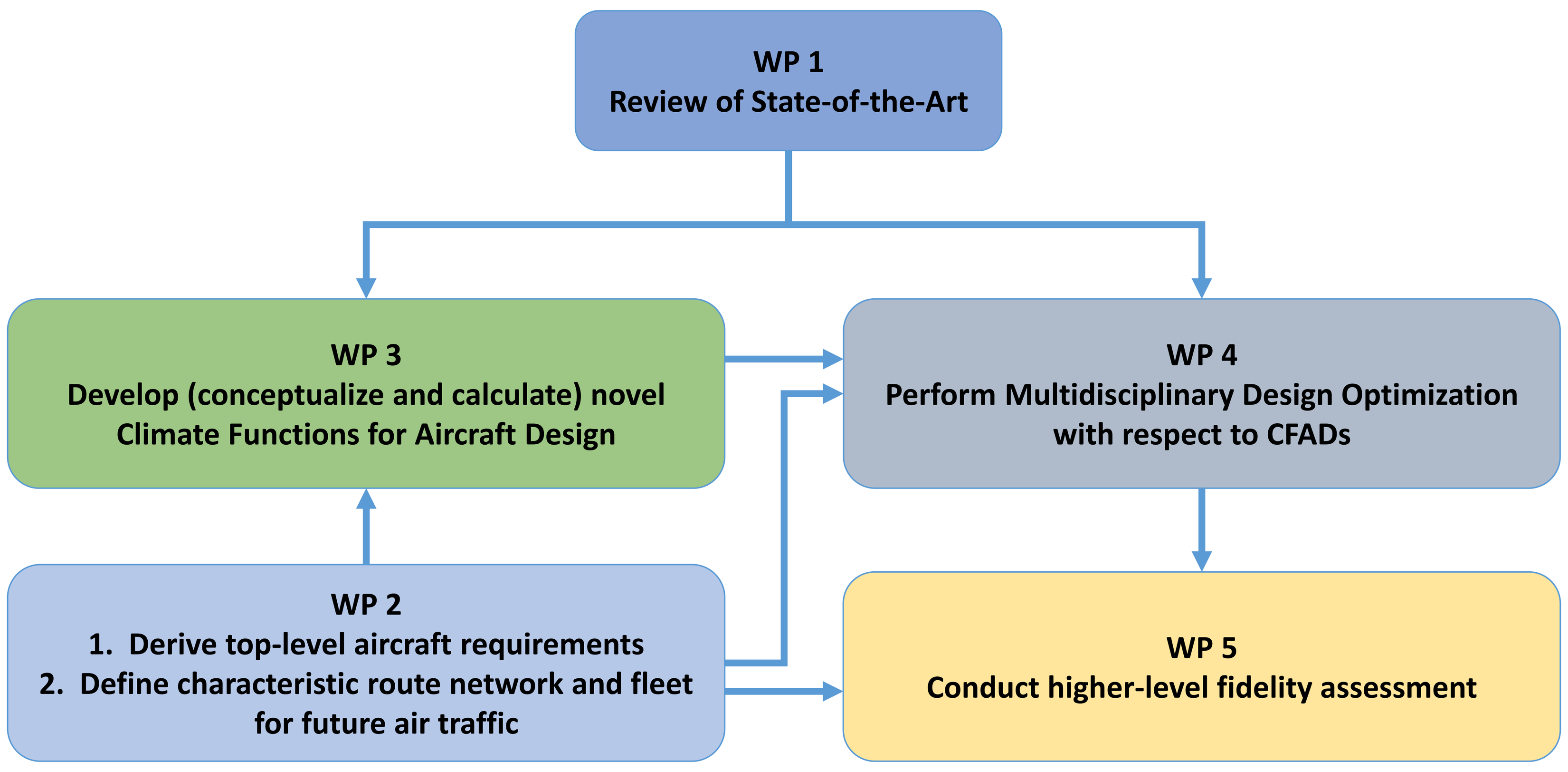
GLOWOPT Approach



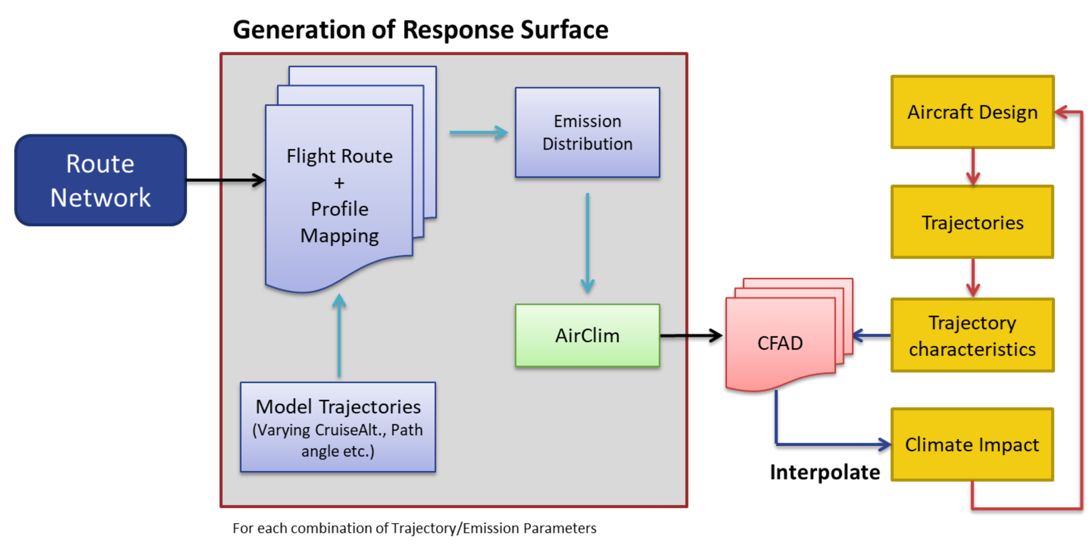
Work package (WP) flow diagram

Climate Functions for Aircraft Design (CFADs)

CFADs will describe in detail the **spatially varying emissions** which are **easily applicable** in the climate assessment of aircraft design

- Consider **both** CO_2 and non-CO_2 effects.
- They will contain the **route network information** in an aggregated way.
- **Common interface** with key input parameters which address both aircraft design process and calculation of climate impact.
- Computationally inexpensive, can be **extended** to other technological areas.

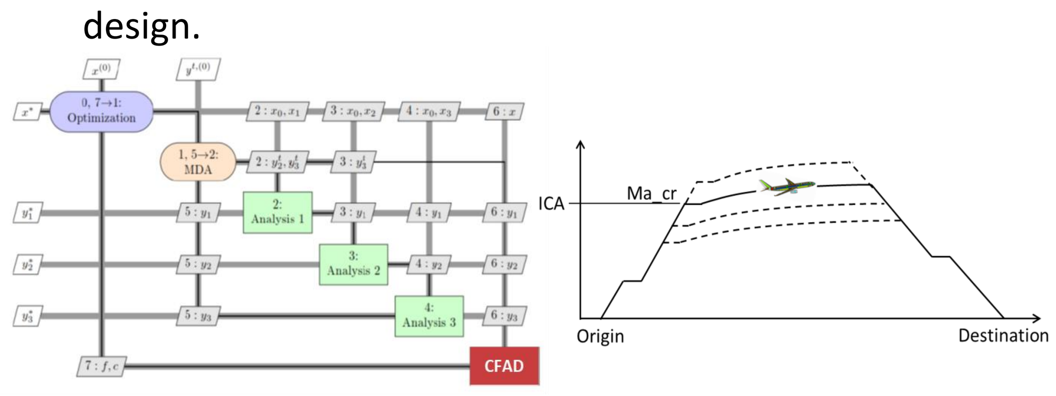
- **Climate metric** to control the weighing of CO_2 and non-CO_2 effects.
- CFADs as **response surfaces** with AirClim modelling environment[3]



Strategy to determine CFADs

Aircraft Design

- **Multidisciplinary aircraft design synthesis method** will be employed to assess the aircraft design using the CFADs. This allows for an analysis of the impact of changing top level requirements or the infusion of new technology.
- **Reference aircraft** will serve as the baseline for comparing the global-warming optimized design.



MDO architecture with CFAD and variation of initial cruise altitude and Mach for optimal relation with climate impact

- Based on the fleet analysis an **envelope for operational parameters** will be established.
- The climate optimal **cruise altitude and Mach number** will be determined within the optimization process.

Summary

GLOWOPT addresses the issue of global warming minimization from multidisciplinary design optimization approach. An interdisciplinary approach to develop climate functions for aircraft design is the high level objective of this project.

CFADs will contain the aircraft fleet level information and describe the effects of both CO_2 and non-CO_2 effects. This will be an easy-to-use tool which can be integrated with existing MDO architecture. The methodology presented in this poster is being developed, validated and demonstrated within GLOWOPT.

Research Consortium

- **Hamburg University of Technology, Germany (Coordinator)**
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