FlyATM4E (SESAR ER)
Mitigating aviation climate impact by climate-optimized aircraft trajectories

SESAR Exploratory Research Project, *Grant No 891317*

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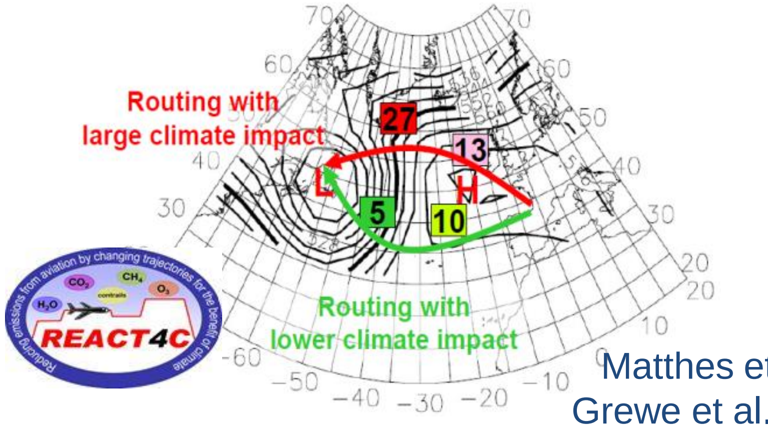
DLR ECATS FlyATM4E SESAR JOINT UNDERTAKING

FlyATM4E Climate-optimization of aircraft trajectories

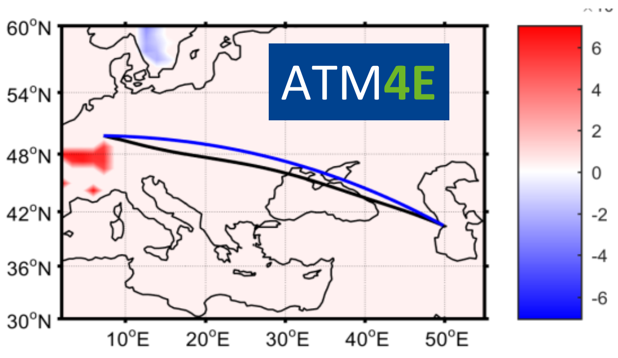
- Aviation is concerned by climate impact of its operations. **Aviation climate impact** is caused by CO_2 and non-CO_2 emissions, comprising impacts of **contrails**, **nitrogen oxides** impacting ozone and methane, **water vapour**, and **aerosol effects**.
- **Non-CO_2 climate impacts** show a strong spatial and temporal variation, which can be exploited when identifying **alternative trajectories**, by avoiding those regions which have a large impact.
- However, during flight planning currently emission information is available, but no **environmental impact information** linked to the emitted amount is available along the trajectory.

Concept: Feasibility study



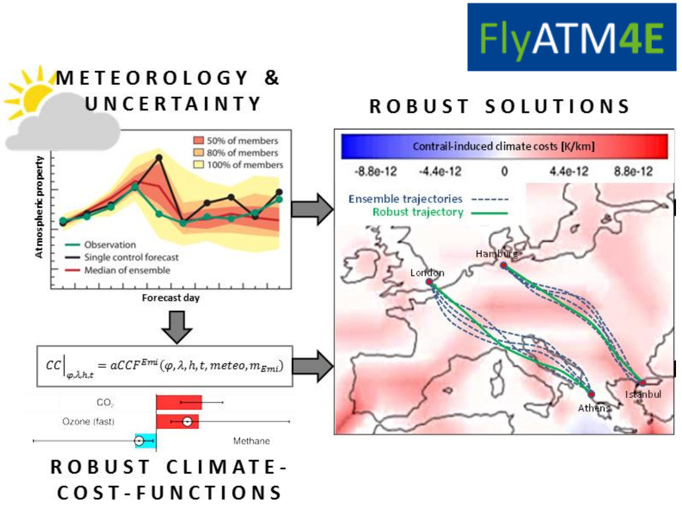
Matthes et al., 2012
Grewe et al., 2014a,b

European Application: Case study



Matthes et al., 2020

Uncertainties and robustness



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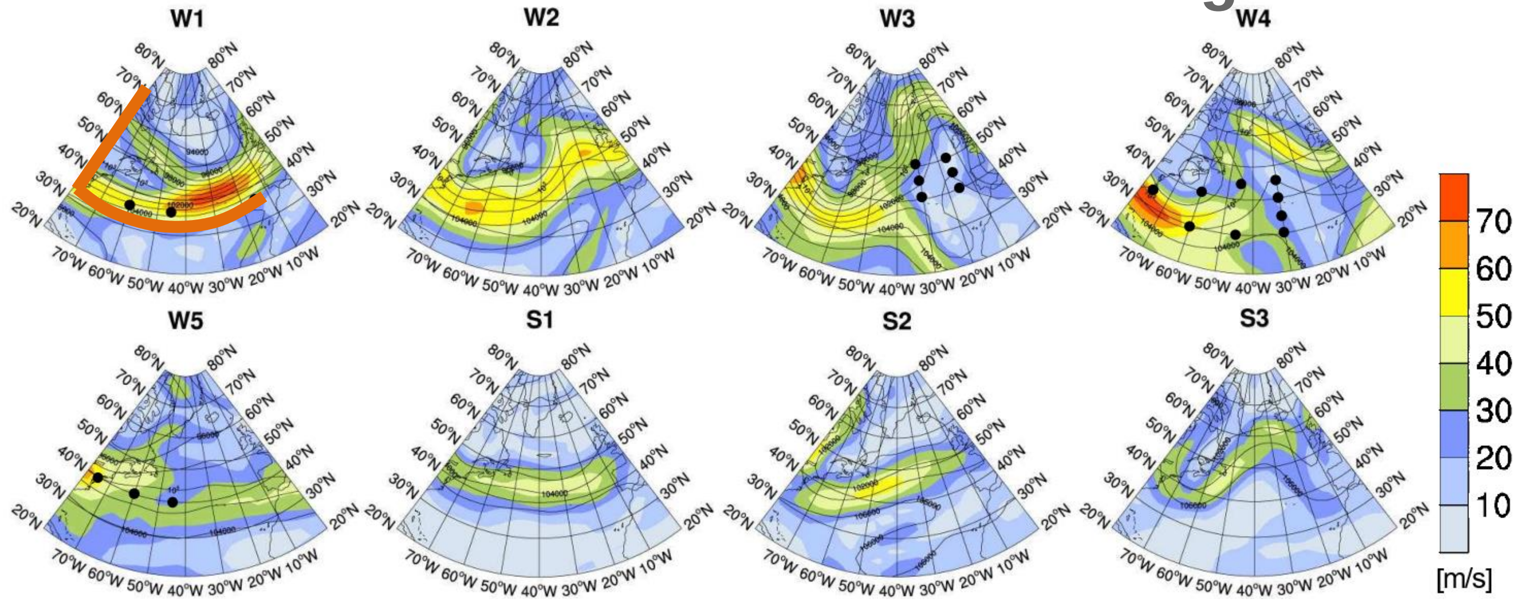
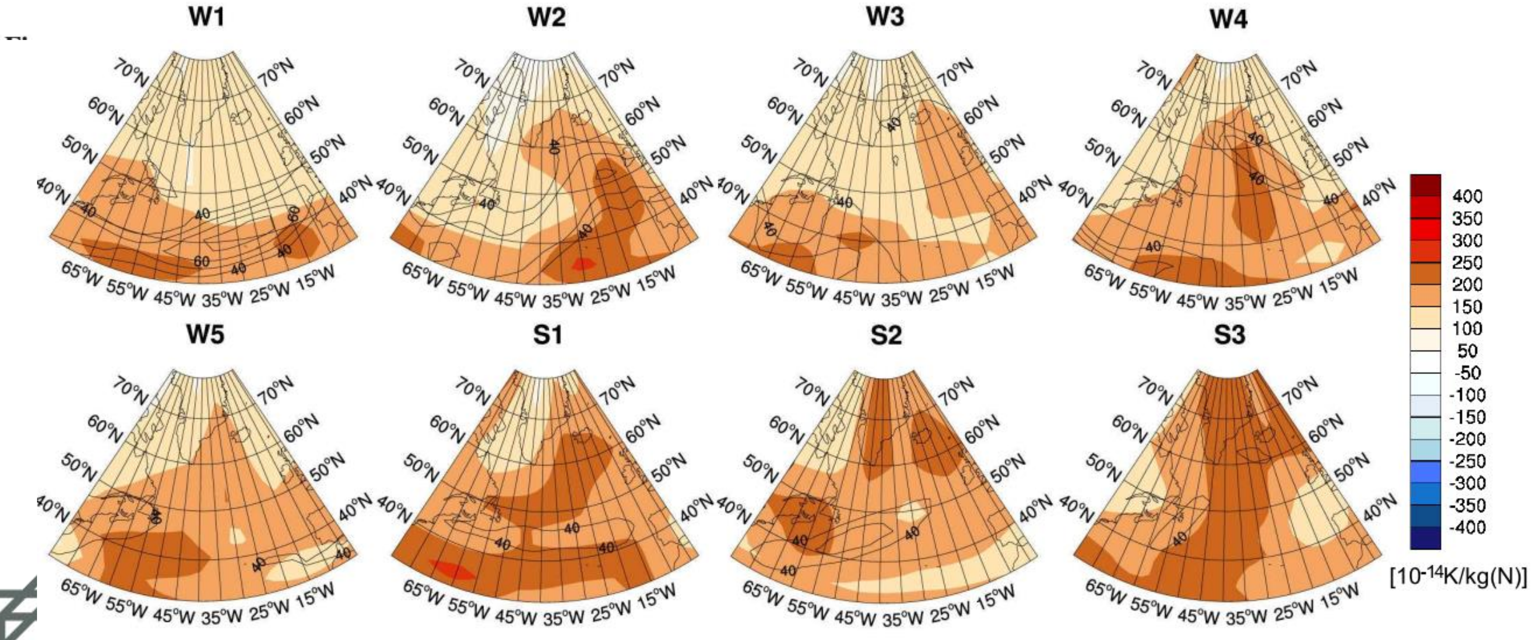
Weather data and Ozone Climate-Change-Functions



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

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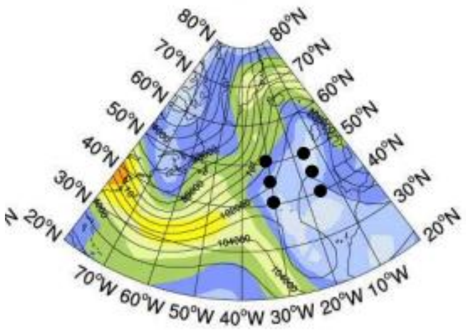
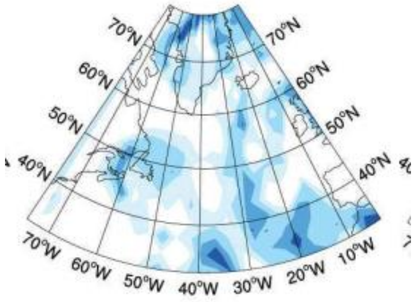
MET Service: Climate Change Functions (CCFs)

respresentative winter
weather situation,
250 hPa

Weather



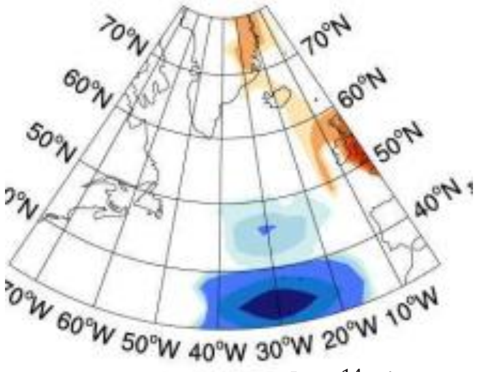
Potential contrail coverage



Frömming et al. 2021

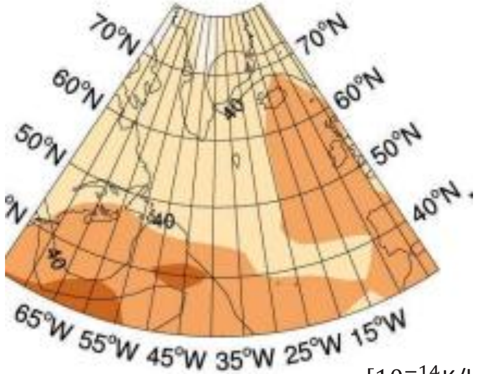
Climate Change Functions = four dimensional functions (space & time)

Contrail CCF



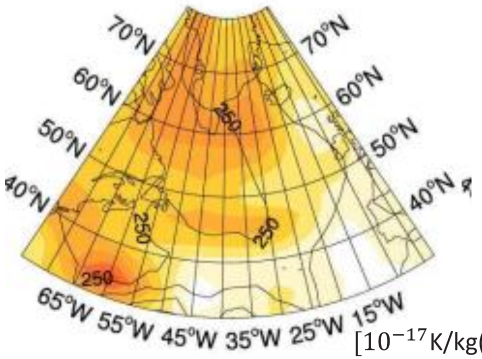
$[10^{-14}\mathrm{K/km(contrail)}]$

Ozone CCF



$[10^{-14}\mathrm{K/kg(N)}]$

Water vapour CCF



$[10^{-17}\mathrm{K/kg(fuel)}]$

- Climate change functions characterize sensitivity of the atmosphere to aviation emissions at specific location (position, altitude, time). ⇒ **MET products for climate-optimized trajectory planning** require spatially and temporally resolved climate impact information.

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Climate impact mitigation potentials of alternative routings

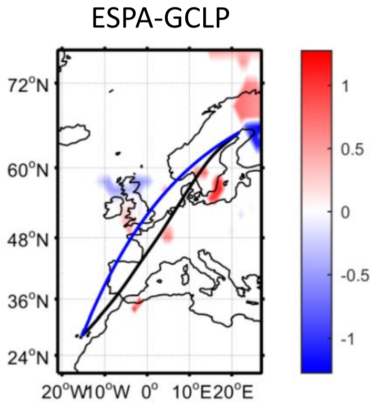
One Day Case Study of European Air Traffic on 18 December 2015

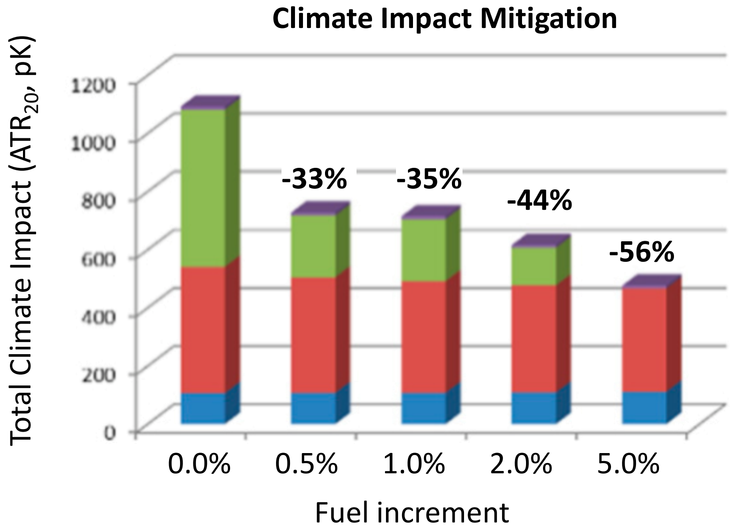
ATM4E

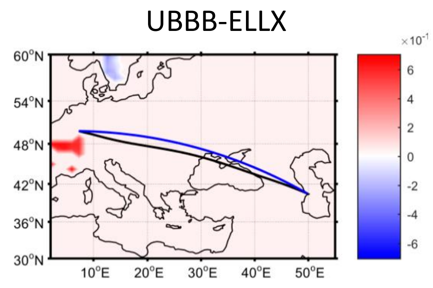
Matthes et al., 2020

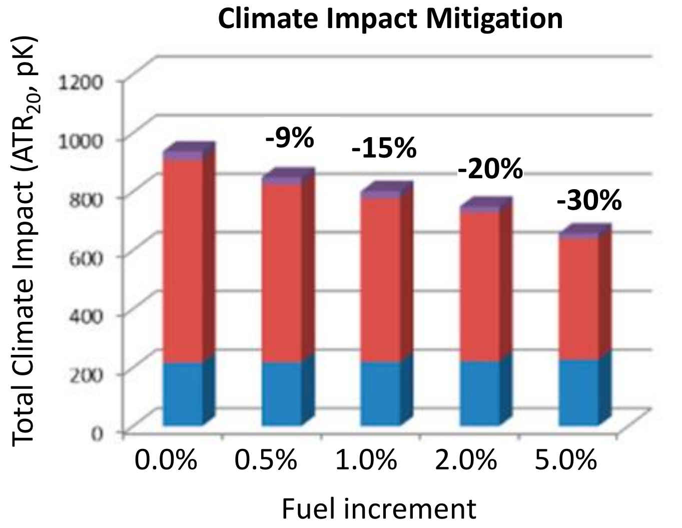
Example 1: Lulea – Gran Canaria (ESPA-GCLP)
Contrails-dominated climate impact

Example 2: Baku – Luxembourg (UBBB-ELLX)
NO_x-dominated climate impact (no contrails)









- **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)

H_2O
AIC
NO_x
CO_2

DLR FlyATM4E SESAR JOINT UNDERTAKING

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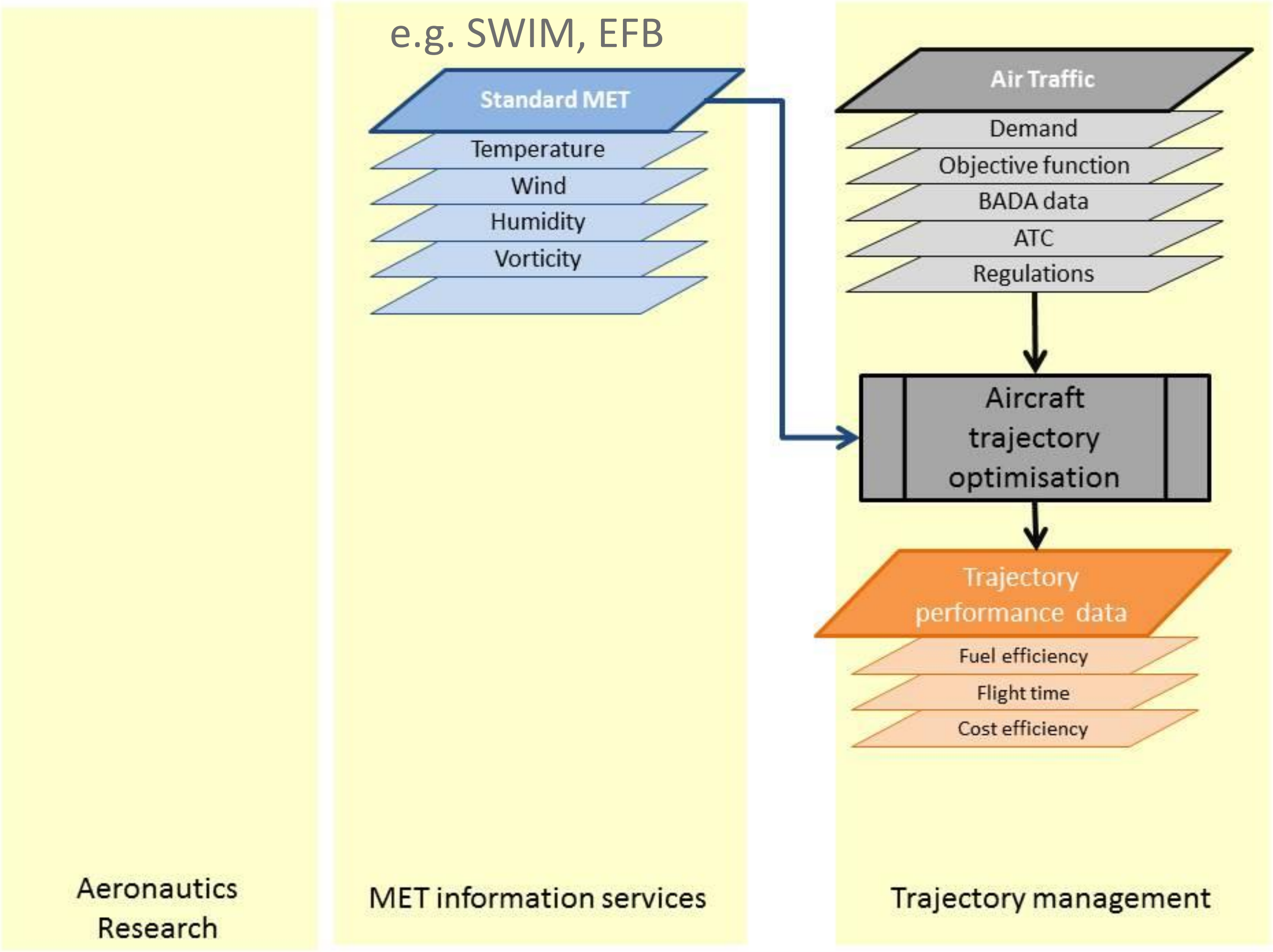
Air traffic management for environment
How to integrate climate change information (aCCFs) during flight planning

Schematic
ATM system



ATM4E

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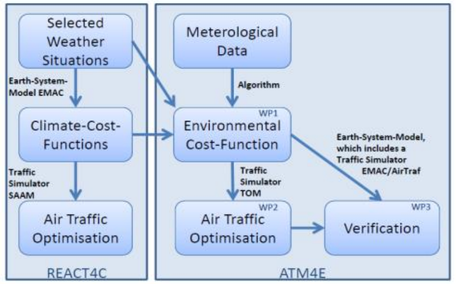
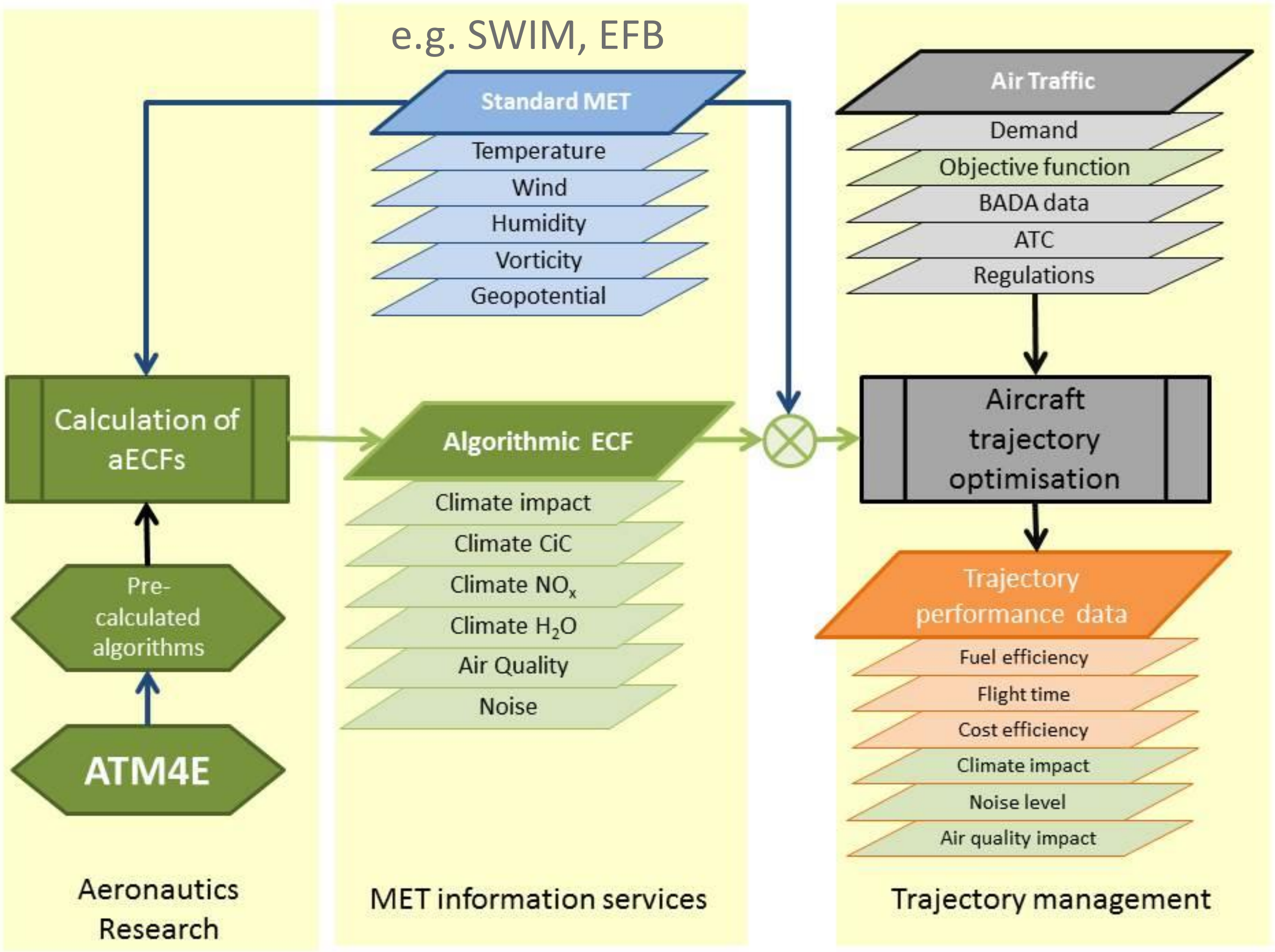
Air traffic management for environment

How to integrate climate change information (aCCFs) during flight planning





Contribution of ATM4E

ATM4E

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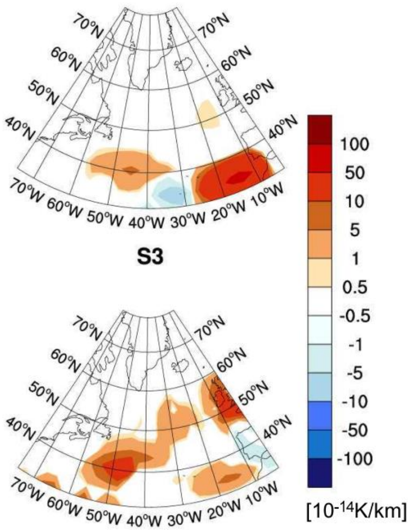
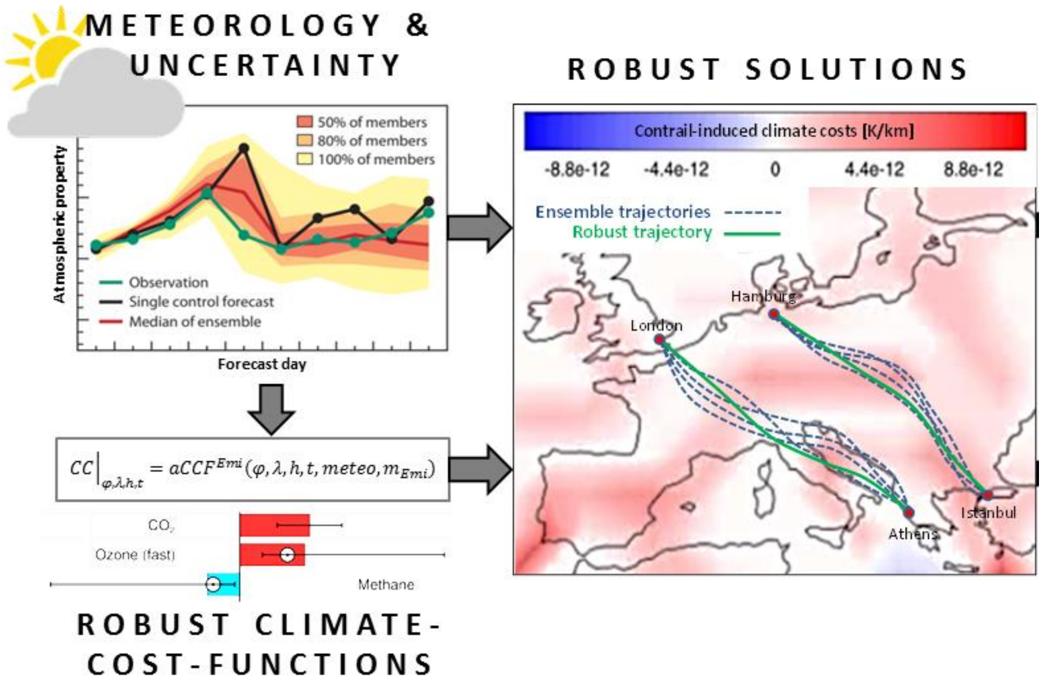
Feasibility study: Step towards robustness of climate-optimized trajectories Using algorithmic Climate Change Functions ECFs (MET service)

- FlyATM4E develops a concept to **identify climate-optimised aircraft trajectories** which enables a robust and **eco-efficient** reduction in aviation's climate impact, quantifying non-CO_2 **mitigation potentials**.
- FlyATM4E **identifies those weather situations** and aircraft trajectories, which lead to a **robust climate impact reduction** despite **uncertainties.** Methods on robust decision making under uncertainty conditions are currently under development, resulting in quantitative estimates of robust mitigation potentials.

NAFC



Frömming et al. 2021



- FlyATM4E further identifies those weather situations having a **large potential to reduce the climate impact** with only little or even no cost changes ("**Cherry-Picking**") and those situations where both, climate impact and costs can be reduced ("**Win-Win**").
- FlyATM4E **formulates recommendations** how to implement these **strategies in meteorological (MET) products**

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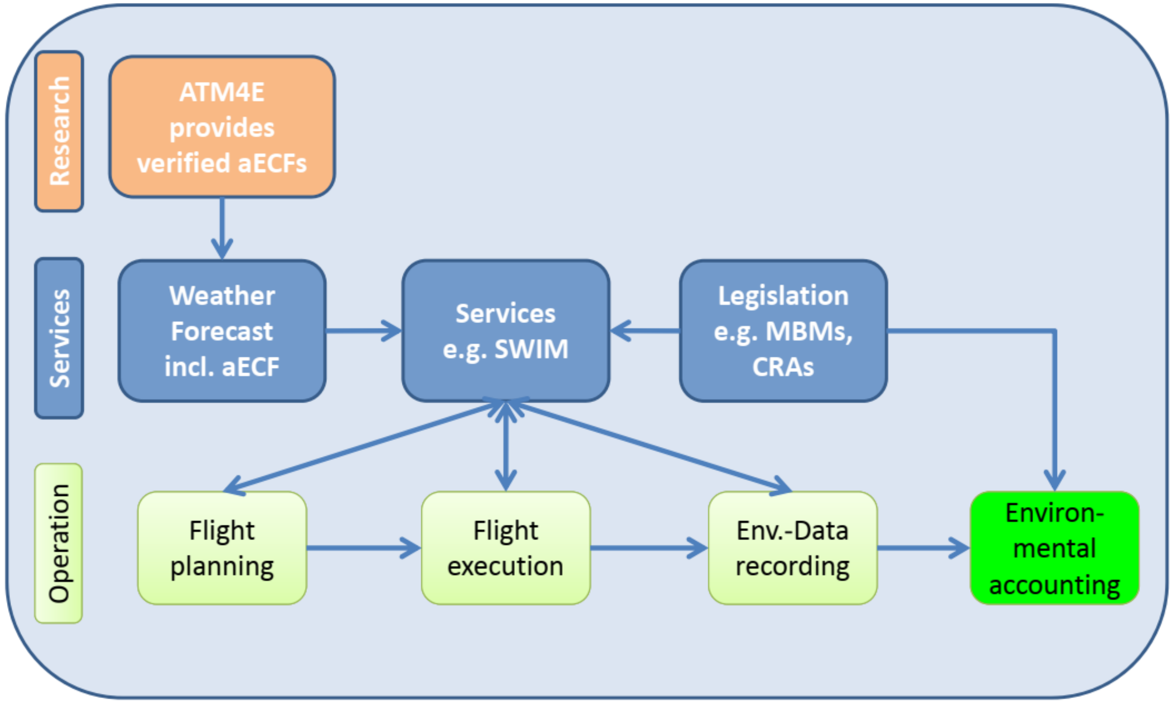
Roadmap: Towards implementation of climate-optimized trajectories

- Implementation relies on **provision of climate change functions to ATM** (trajectory optimisation)
- Feasibility study performed on **infrastructure** comprising MET components – resulting in roadmap definition how to expand the current ATM system in order to **enable climate-optimized trajectories**

- Options **on how to develop and how to integrate** such novel MET products have been studied in earlier projects Aeronautics (REACT4C) and SESAR (e.g. ATM4E, PJ18) and achievements are published.
- Further options on how to expand current ATM and how to identify overall **mitigation potential by climate-optimized trajectories** are currently explored, e.g. ongoing SESAR (Exploratory Research) FlyATM4E, ALARM, but also in Aeronautics projects ClimOP



Matthes et al. 2017

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Thank you

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