



Tradeoffs in Airport Air Quality, Noise and Climate Impact

ATM4E

ATM for Environment

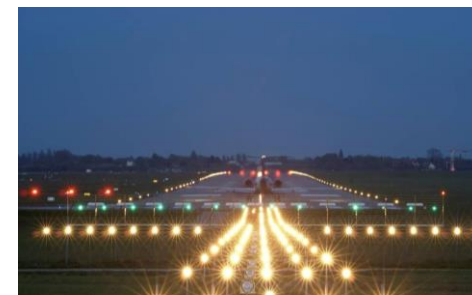
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SESAR Webinar on Environment, 20 Nov 2020





Motivation

Airport Air Quality, Noise and Climate Impact

- Aircraft operations are concerned by their environmental impacts, comprising **air quality** and **noise**, and **climate impact**
- Current **regulation** and **guidance** documents address a certain number of issues while not yet covering all environmental impacts occurring
- It is desirable to be able to assess **individual environmental impacts** along a planned trajectory during optimisation.

Table 2-1. Local air quality regulations in different countries

Country/ Organization	Pollutant (averaging period)	Sulphur dioxide			Nitrogen dioxide			Carbon monoxide		Ozone			PM ₁₀	
		1 hour*	24 hours	Annual	1 hour	24 hours	Annual	1 hour	8 hours	1 hour	8 hours	24 hours	24 hours	Annual
		µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
WHO	WHO Guidelines	—	125	—	200	—	40–50	30	10	—	120	—	—	—
EU	Air Quality Framework Directive	350	125	20	200	—	40	—	10	—	120	—	50	40
Australia	National Environmental Protection Measure for Ambient Air Quality	520	200	50	220	—	50	—	10	200	—	—	50	—
Brazil	Resolution 03 of CONAMA (National Council for the Environment), June 1990 — Air Quality National Standards	—	365	80	320	—	100	40	10	160	—	—	150	50
Canada	National Ambient Air Quality Objectives, Canadian Environmental Protection Act, June 2000	900	300	60	400	200	100	35	15	160	—	50	—	—

Source: Doc 9889, Airport Air Quality Manual

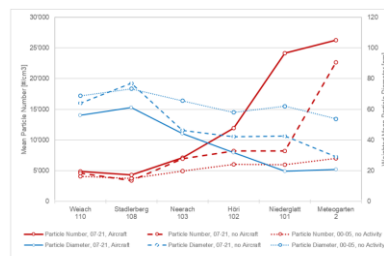


Figure 10 Mean particle number and size in daytime (with/without aircraft activity) and during night-time
Source: ZRH Airport Study, 2019

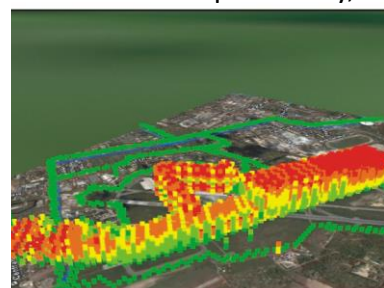


Figure 4.4. Example of 3-D geospatial emissions inventory

TABLE 2: Evolution of Annex 16

Meeting	Year	Key recommendation on Annex 16 SARPs
Special Meeting on Aircraft Noise in the vicinity of airports	1969	First Edition of Annex 16 – Aircraft Noise
CAN2	1972	Noise Standards for light aeroplanes
CAN6	1980	Noise Standards for helicopters and supersonics with Type Certification submitted before 1 January 1975
CAEE2	1981	First Edition of Annex 16, Volume II - Aircraft Engine Emissions
CAEP1	1986	Noise Standards for light propellers
CAEP2	1991	Noise Standards for light helicopters
CAEP2	1991	Increase in Stringency of NO _x Emissions
CAEP4	1998	Increase in Stringency of NO _x Emissions
CAEP5	2001	Increase in stringency for turbojet and heavy-propeller noise Standards (Chapter 4)
CAEP6	2004	Increase in Stringency of NO _x Emissions
CAEP8	2010	Increase in Stringency of NO _x Emissions
CAEP9	2013	Increase in stringency for turbojet and heavy-propeller noise Standards (Chapter 14) Noise Standards for Tiltrotors (Chapter 13)
CAEP10	2016	nvPM engine emissions Standard
CAEP10	2016	First Edition of Annex 16, Volume III - Aeroplane CO ₂ Emissions
CAEP Steering Group	2017	First Edition of Annex 16, Volume IV (CORSIA)
CAEP11	2019	nvPM mass and number emission Standard

Legend:

Noise	Local Air Quality	Climate Change
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Source: 50 years of Annex 16 – the Special Meeting on Aircraft Noise in the Vicinity of Airports

Motivation

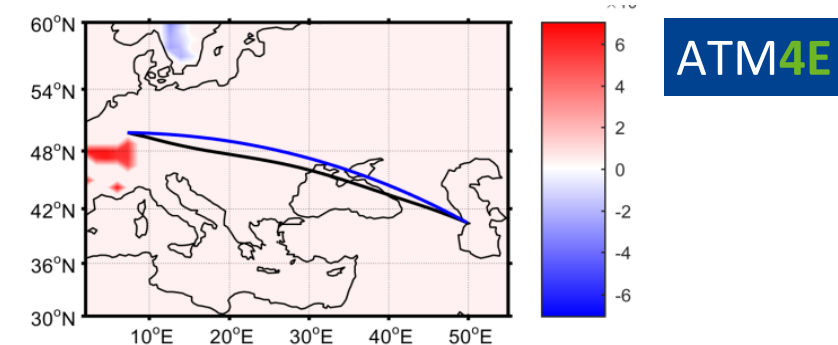
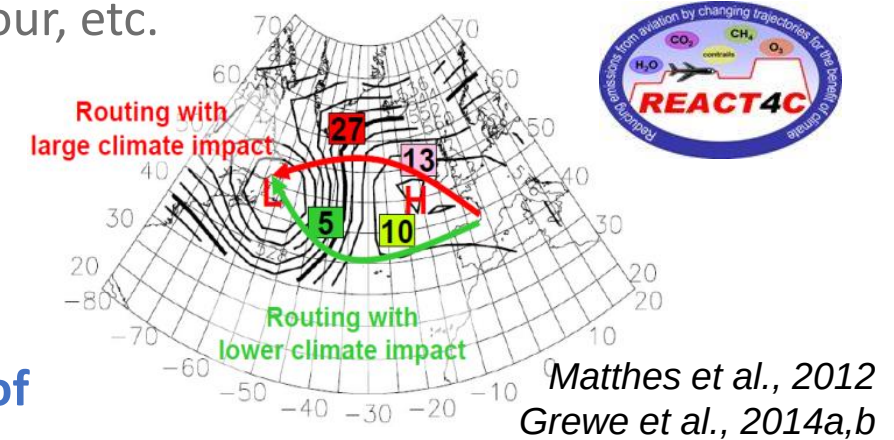
Airport Air Quality, Noise and Climate Impact

- Integrating existing methodologies for **assessment of the environmental impacts** of aviation, in order to evaluate the implications of environmentally-optimized flight operations, considering **climate impact**, **air quality** and **noise impacts**
- In earlier studies, information on **environmental impacts** was derived from **'offline'** comprehensive model calculations comprising complex chemistry-climate models, air quality assessment models and noise models.
- However, the idea is that during **trajectory planning** such information should be available, in order to assess and mitigate **the environmental impact** of aircraft operations.
- Here, we propose to develop a method that allows an **efficient integration** of such environmental change functions (data) via an algorithm based on MET forecast.
- These **algorithm based ECFs** can serve to expand planning tools in order to be able to assess and optimize the **environmental impacts** of individual aircraft trajectories.



ATM4E Environmental-optimised trajectories

- Aviation is concerned by environmental impact of its operations, comprising **air quality, noise** and climate impact. **Aviation climate impact** is caused by CO₂ and non-CO₂ emissions, comprising contrails, nitrogen oxides impacting ozone and methane, water vapour, etc.
- However, during flight planning currently emission information is available, but no **environmental impact information** linked to the emitted amount is available along the trajectory.
- ATM4E**, Exploratory Research project **SESAR 2020** (2016-2018)
- Main objective** of the ATM4E project was to explore the **feasibility of a concept for environmental assessment** of ATM operations working towards environmental optimisation of air traffic operations in the European airspace.
- Explore a **multi-dimensional** and **multi-criteria** optimization.



Matthes et al., 2020



This project has received funding from the SESAR Joint Undertaking under grant agreements No 699395 and No 891317 under European Union's Horizon 2020 research and innovation programme.



Generating Environmental Change Functions

Local Air Quality (LAQ)

- Establish a **source-receptor relationship**: emission to air quality impacts
- The LAQ ECFs are based on simulations designed to evaluate the sensitivity of ground air quality levels with respect to aircraft NO_x emissions, providing 3d-information.
- LTO cycle: Emissions below 3000ft, taxiing emissions *not* included
- Simulations performed with Eurocontrol's Open-ALAQs/AUSTAL2000
- Full LAQ assessments for 2 prominent airports (LEMD, EDDH)

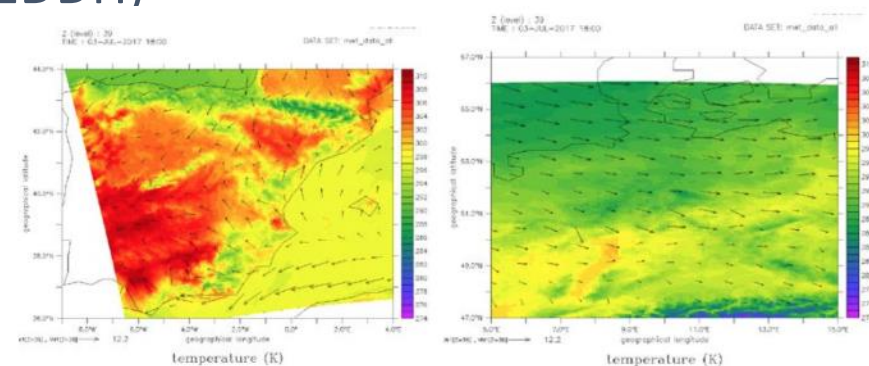
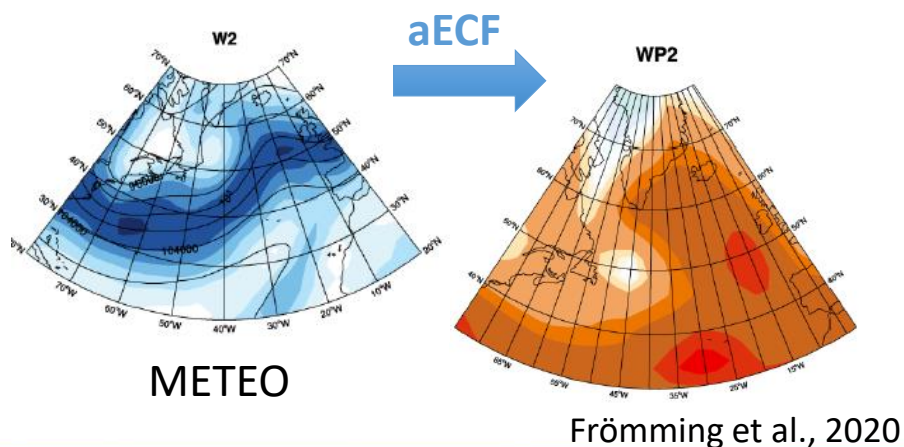


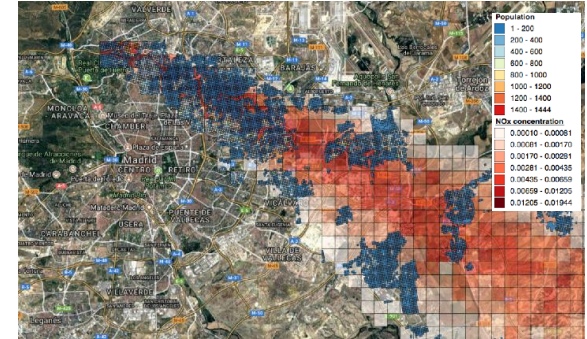
Figure 6: Windfield over Madrid and Hamburg.

Source: ATM4E Final Project Report, 2018.

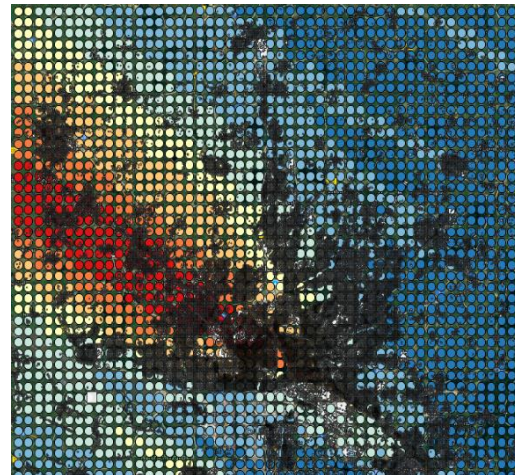
Example LAQ Environmental Change function

Population weighting

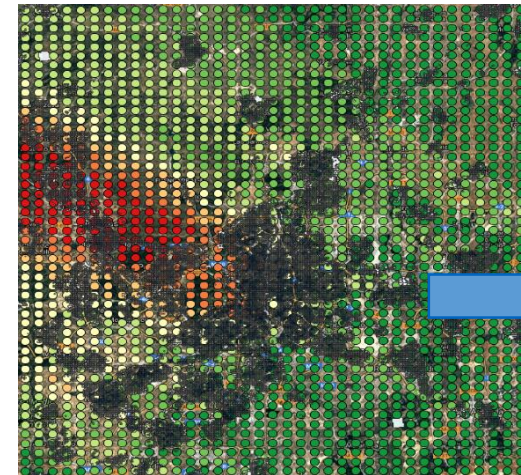
- The environmental impact is calculated by combining the local air quality (LAQ) results with the number of people exposed to the calculated NO_x levels.
- A basic LAQ metric is the emitted amount of respective component relevant for air quality, e.g., nitrogen oxides or particulate matter, below a specific altitude.
- A LAQ ECF is a **population-weighted value** that is **mapped back to the source** (distance, altitude) to provide a measure of how a specific aircraft emission impacts local environment (within a 30 km radius from the airport reference point).



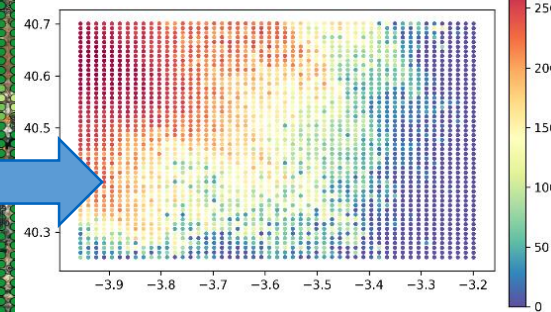
Hamburg



Madrid



Z = 600m



Surface level local air quality (ECF). The population density is superposed on the population-weighted NO_x concentration.

Surface LAQ ECF Madrid.

Source: ATM4E Final Project Report, 2018.

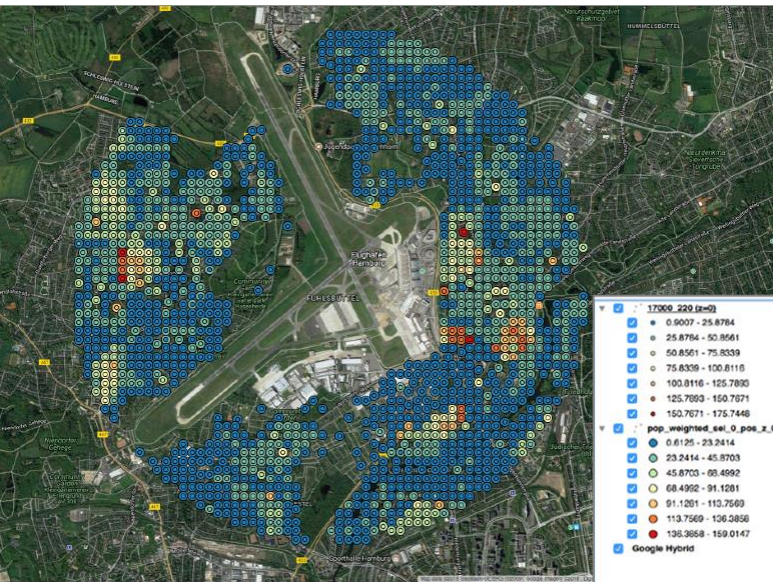
Generating Environmental Change Functions

Noise – Summarizing main challenges

3 sets of simulations

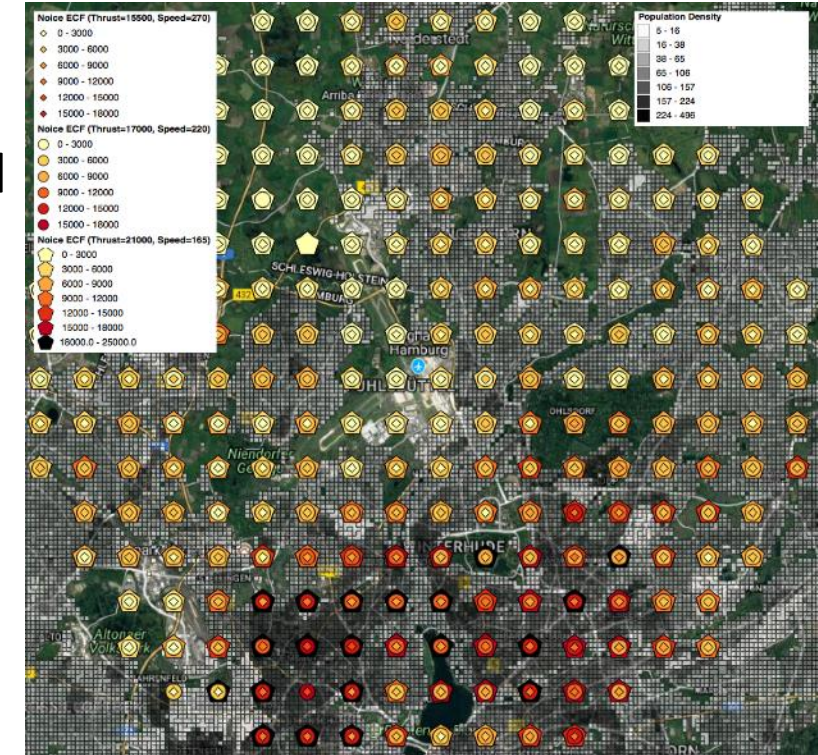
CNT ₁ (lb)	15500	17000	21000
Speed ₁ (kt)	270	220	165

Population weighted Noise for one
“noise-emitting” point



Hamburg,
ATM4E Final Project Report, 2018.

- Noise is **more complex** than local air quality ECFs, as they have to be **multidimensional** to account for all relevant parameters
- The noise metric used has to be put into context
- Optimising for noise** is subject to operational and safety constraints
- Future ECFs will have to consider **annoyance** as well
- However, noise ECFs will enable to identify **favourable** trajectories

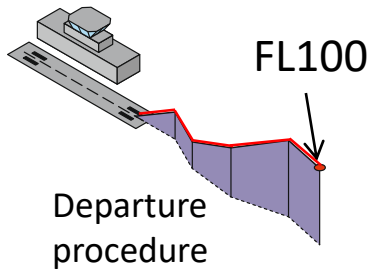


Source: ATM4E Final Project Report, 2018.

Optimisation of trajectories to minimise environmental impacts

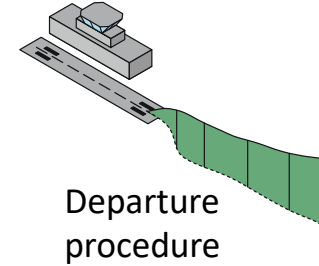
Results (takeoff, approach)

Departure
airport

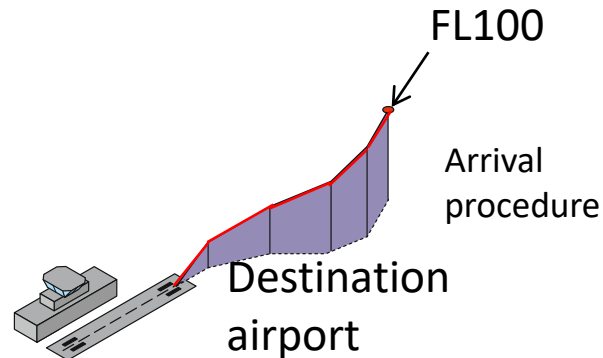


- One-day case study Dec 18th 2015
- City pair Hamburg-Madrid
- Trajectory Optimisation: Green trajectories compared to fuel minimal solution
- Air Quality impact can be mitigated

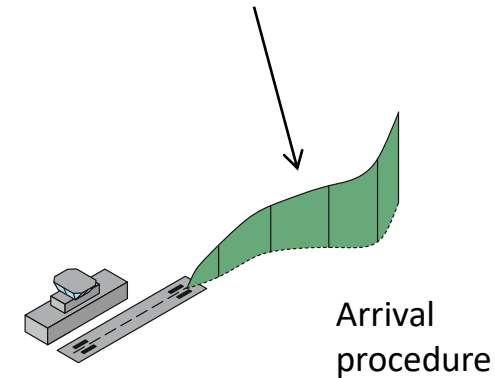
Departure
airport



Environmentally-optimized
Takeoff/Approach trajectories



Destination
airport



ATM4E

SESAR
digital academy



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Feasibility study

Optimisation of trajectories to minimise environmental impacts (WP2)

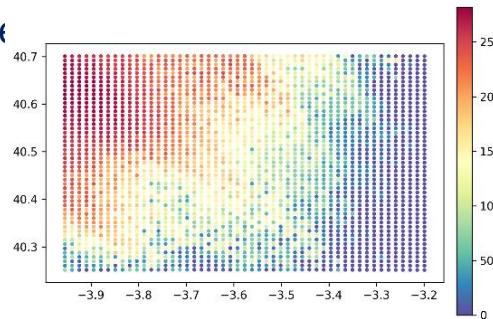
Results (LAQ) EDDH (Hamburg, Germany) – LEMD (Madrid, Spain)

■ Trajectory optimisation with regard to LAQ ECF covering the NO_x effects

- High potential to improve LAQ caused by NO_x emissions of up to 60%
- Large improvements for small fuel penalties possible
- Absolute impact much larger for takeoff segment than approach segment

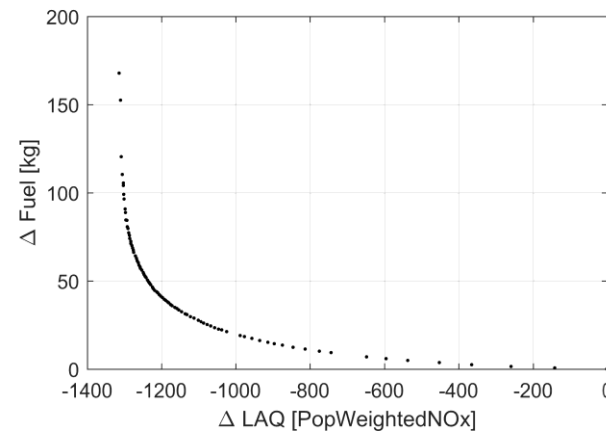
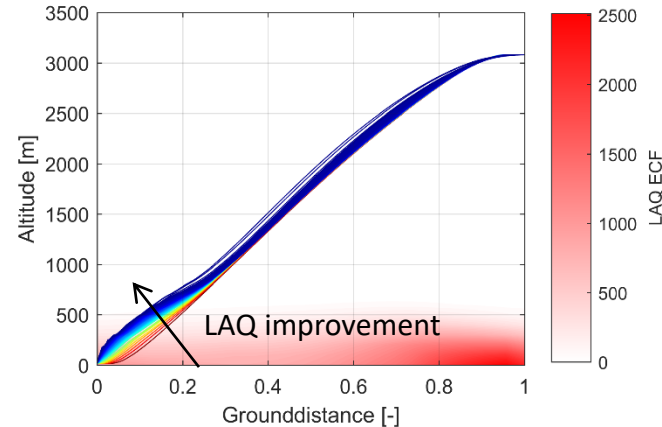
■ HC, soot and particle emissions were not considered in ATM4E

- Might have considerable impact on approach segment

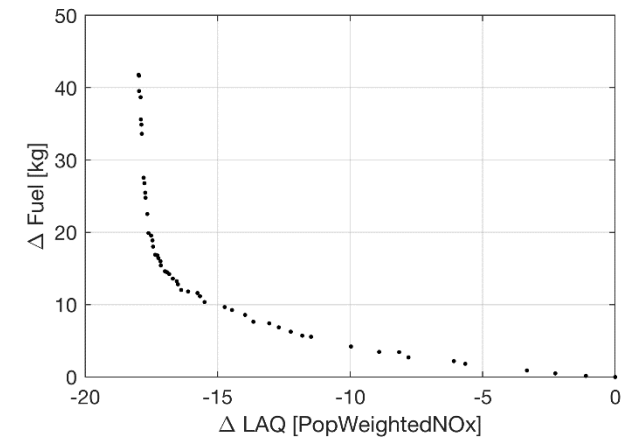
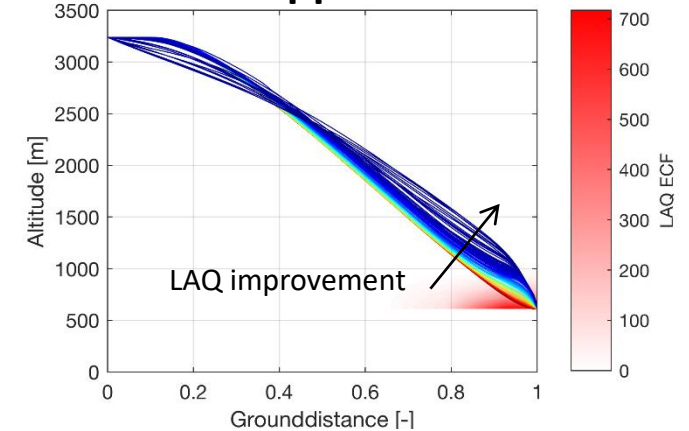


ECF NO_x impacts, ATM4E Project 2018.

Takeoff



Approach



Source: ATM4E Final Project Report, 2018.

Identified research needs in ATM4E on Environmental Change functions

1. **Enhancing the technological readiness of the algorithmic environmental change functions (aECF):** these need to cover all aircraft starting and landing in European airspace and represent uncertainties
2. **Expand the aECF concept from a case-study approach to a full European-scale application including performance indicators:** this would also need to consider expanding the aECFs (e.g. for air quality, other pollutants; for noise, the impact of airframe; for climate, additional non-CO₂ effects)
3. **Expand the aECF concept to include a robustness measure to minimize the risk of wrong decisions:** this would need to account for uncertainties in weather forecasts, environmental impacts, and exact routing knowledge



FlyATM4E

ATM4E

Ongoing research projects

Local Air Quality, Noise, Climate Change

- **FlyATM4E** investigates robustness criteria when identifying **climate-optimized aircraft** trajectories and synoptical situations with large mitigation potential
 - Assessment strategies: Win-win situations and Cherry picking in the European Air Space
 - SESAR Exploratory Research Project, 06/2020-11/2022, coordinated by DLR Institute of Atmospheric Physics
- **DYNCA**T will explore more **environmentally friendly** and more **predictable flight profiles** in the terminal manoeuvring area, or TMA. It will support pilots in their configuration management during approach.
 - DYNCAT will have available data (real-world, simulation)
 - SESAR Exploratory Research Project, 07/2020-12/2022, coordinated by DLR Institute of Flight Systems
- **ACACIA** improves **scientific understanding** on mechanisms and processes causing **aviation climate impact** and provides an updated climate impact assessment
 - Investigate non-CO₂ climate impacts of aviation comprising indirect aerosol cloud interaction
 - Aeronautics Project (RIA), 01/2020-06/2023 coordinated by DLR Institute of Atmospheric Physics
- **ClimOP** assesses strategies for **operational improvements** in order to reduce climate impact of aviation comprising CO₂ and non-CO₂ impacts
 - Most promising mitigation strategies are identified and their mitigation potential assessed
 - Aeronautics Project (RIA), 01/2020-06/2023, DeepBlue, DLR, NLR, TU Delft et al.



ATM4E



ATM4E

SESAR Webinar on Environment, 20 Nov 2020

Dr. Sigrun Matthes, DLR Germany



*Thank you very much
for your attention!*

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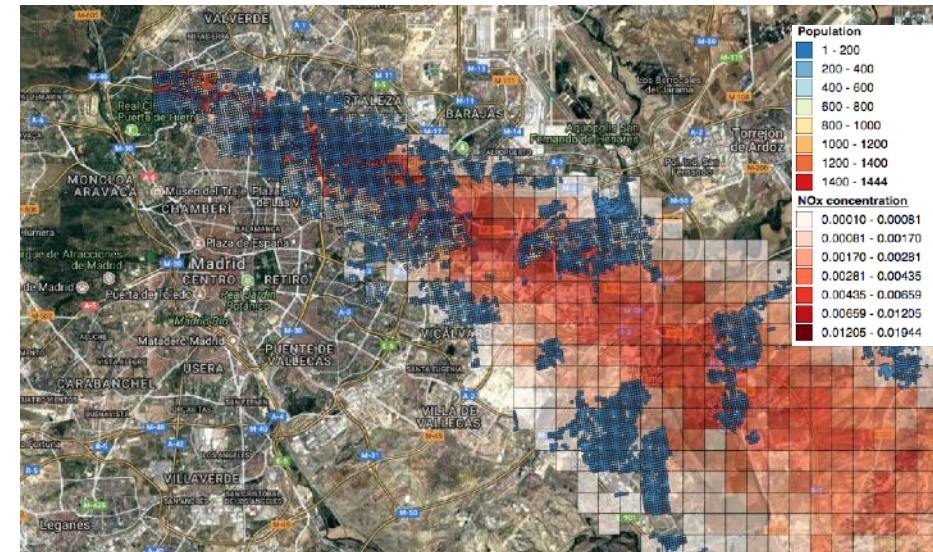
Objectives versus Achievements

Environmentally-optimized flight planning

- **O1 Integrate existing methodologies for environmental assessment in ATM**
 - ✓ Integrated information on environmental impact in ATM by the **use of algorithmic Environmental Change functions (aECFs)** as advanced MET service in order to consider climate, air quality and noise impacts.
- **O2 Expand concept to a multi-dimensional environmental impact assessment**
 - ✓ Concept for multi-dimensional analysis has been **developed** and **published**
- **O3 Analyse traffic in Europe understand mitigation potential and traffic flows**
 - ✓ **Case study** performed for Europe, **mitigation potential** estimated, **verified** with chemistry climate model, and identified **changes** in traffic **flows**
- **O4 These findings will be used to prepare a roadmap on necessary steps**
 - ✓ **Roadmap developed** and discussed with stakeholders identifying steps and actions that would need to be taken **to introduce environmentally-optimized flight operations**

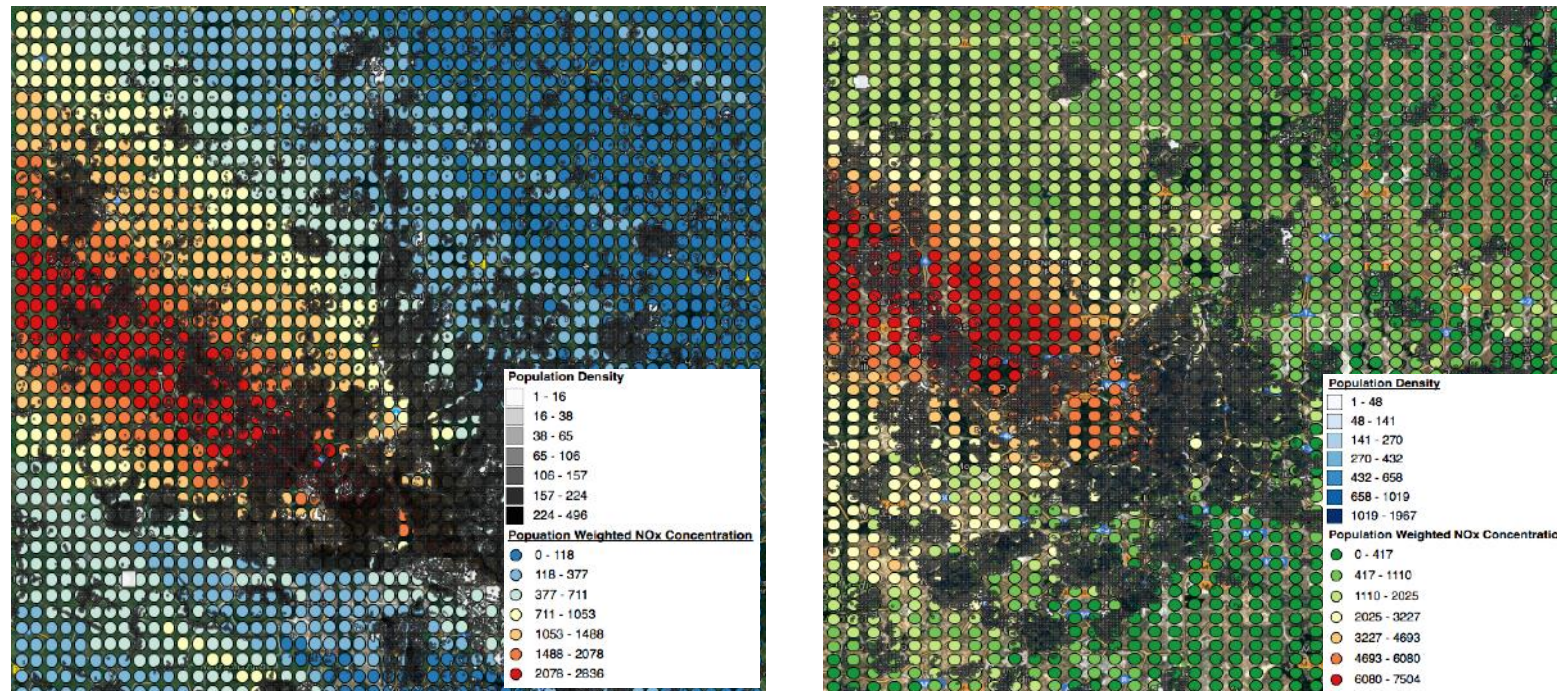
Population weighting

- The environmental impact is calculated by combining the local air quality (LAQ) results with the number of people exposed to the calculated NO_x levels.
- A basic LAQ metric is the emitted amount of respective component relevant for air quality, e.g., nitrogen oxides or particulate matter, below a specific altitude.
- The final proposed ECF is a **population-weighted value** that is **mapped back** (distance, altitude) **to the source** to provide a measure of how a specific aircraft movement impacts local environment (within a 30 km radius from the airport reference point).



Source: ATM4E Final Project Report, 2018.

Example LAQ Environmental Change function

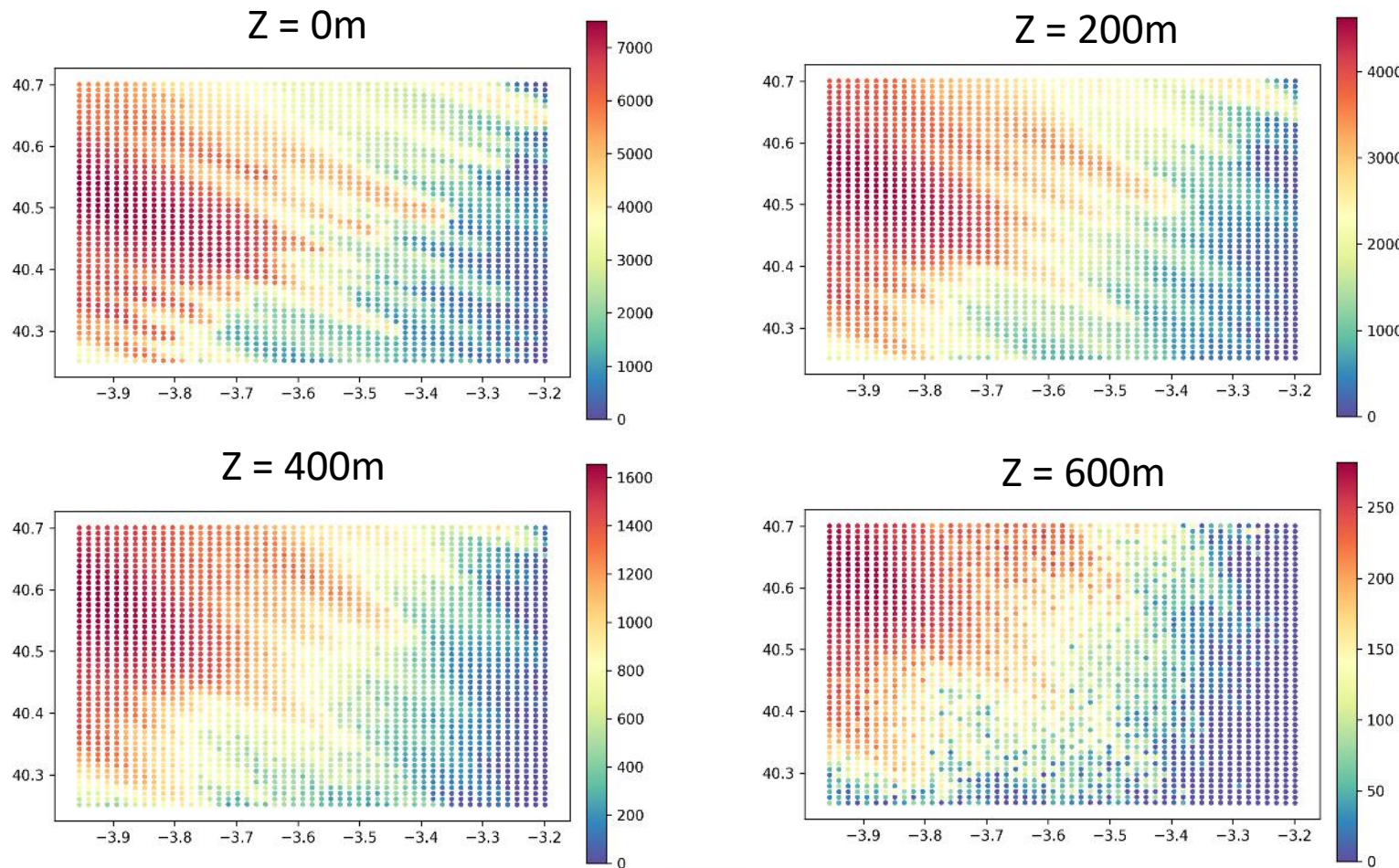


Surface LAQ ECF for Hamburg Airport (left), Madrid (right). The population density is superposed on the population-weighted NO_x concentration.

Source: ATM4E Final Project Report, 2018.

Example Local Air Quality Environmental Change Function Madrid

Population Weighted NO_x



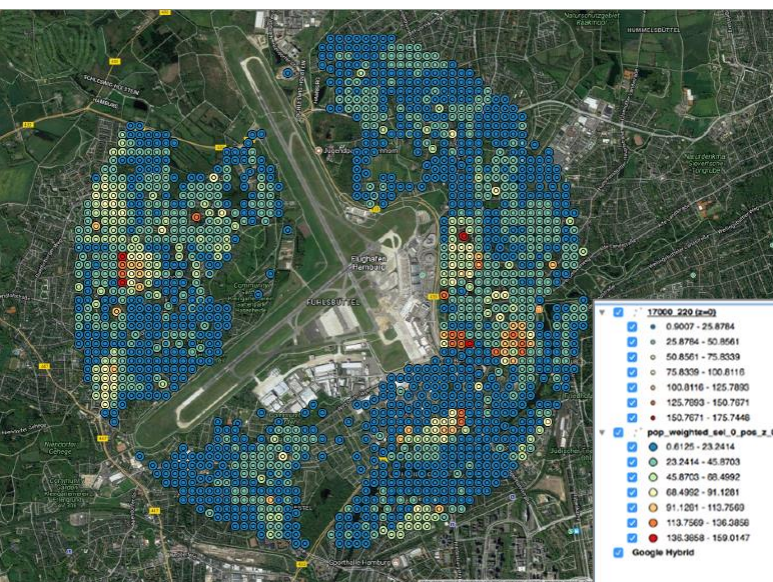
Generating Environmental Change Functions

Noise

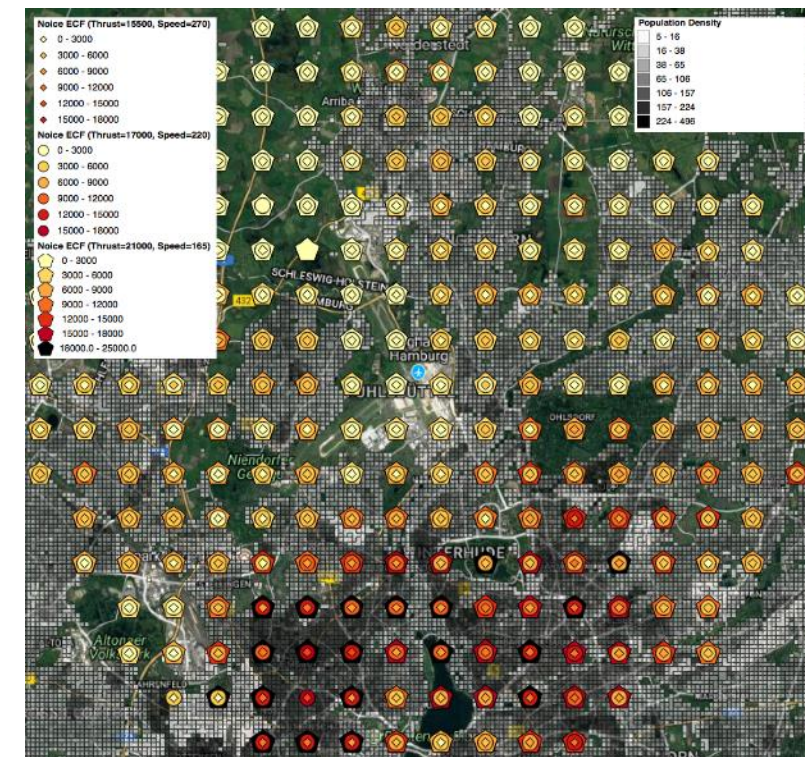
3 sets of simulations

CNT ₁ (lb)	15500	17000	21000
Speed ₁ (kt)	270	220	165

Population weighted Noise for one “noise-emitting” point



- 5D noise ECFs for Hamburg Airport.
- Single-event levels are calculated for different aircraft thrust and speed settings.
- The results are then combined with population data (shown in grey) to estimate the number of people affected by each noise level. Illustration here is for 33-36 dB noise level

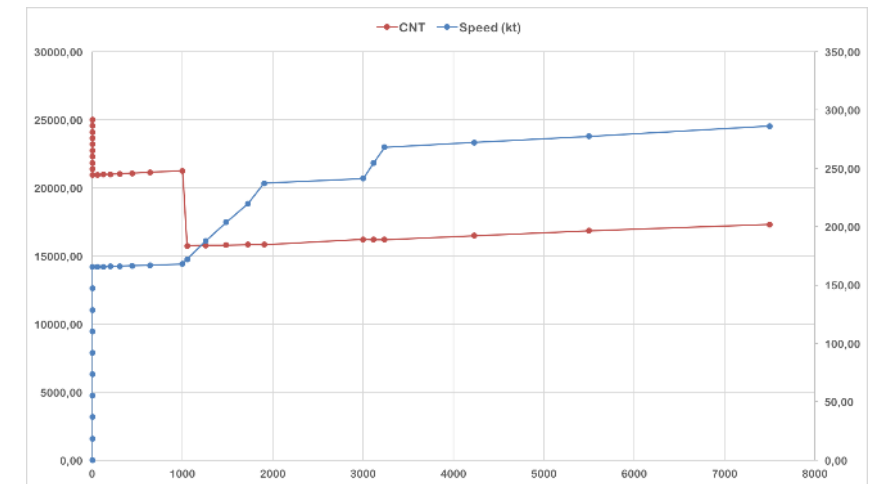


Source: ATM4E Final Project Report, 2018.

Generating Environmental Change Functions

Noise (Local)

- Noise ECFs generated from a single aircraft is centred on a customised version of Eurocontrol's multi-airport noise impact assessment model STAPES (SysTem for AirPort noise Exposure Studies).
- The population around the airport is estimated in the same way as for the LAQ ECFs.
- The core methods from STAPES are used here to effectively determine noise levels from single aircraft movements.
- Following a similar methodology as for LAQ, separate simulations are performed for a set of points defined to simulate an aircraft flight path.
- Single-event levels are calculated from the customised version of STAPES for different aircraft thrust (i.e. 15500, 17000, 21000 lb) and speed (i.e. 270, 220, 165 kt) settings according to the NPD distances provided in Eurocontrol's ANP database.



CNT (lb)	15500	17000	21000
Speed (kt)	270	220	165

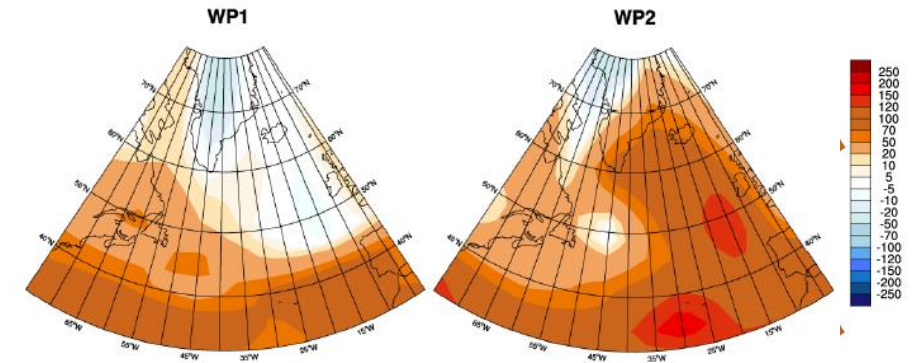
Challenges identified

- Noise is far more complex than LAQ
- Noise ECFs have to be multidimensional to account for all relevant parameters
- The noise model used accounts only for some determined geometric and operational parameters
- Considerable computation time is needed for the production of Noise ECFs (even for the reduced set of parameters examined)
- The metric used has to be put into context
- Optimising for noise is subject to operational and safety constraints
- Future ECFs will have to consider annoyance as well

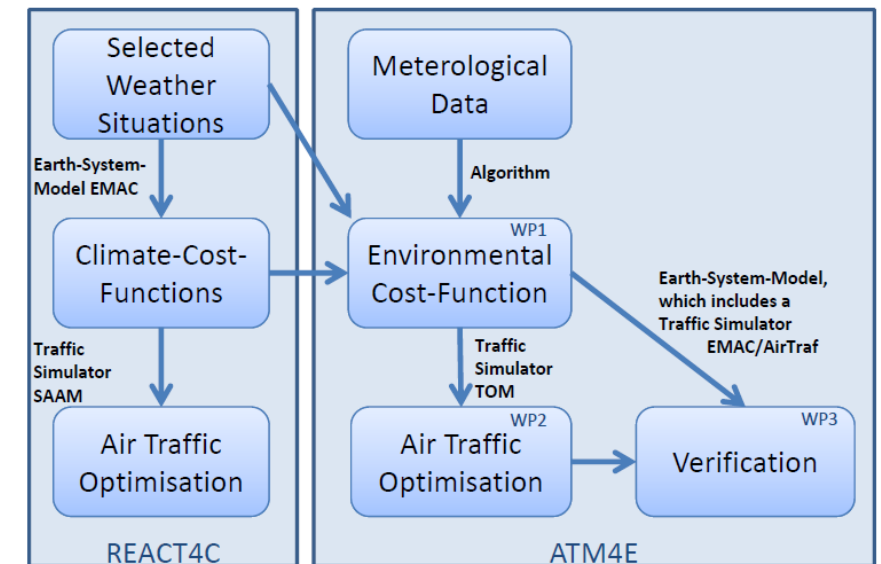


Environmental Change Functions ECFs

- The key step in ATM4E is to relate readily-available meteorological data to these existing detailed CCFs to allow the rapid generation of new CCFs (algorithmic CCFs) for specific (forecast) weather situations
- ⇒ Advanced MET information
- Integration of environmental impact information in trajectory optimization and flight planning process e.g. via Meteorological interface to SWIM infrastructure (format, architecture) to make it available during flight planning.

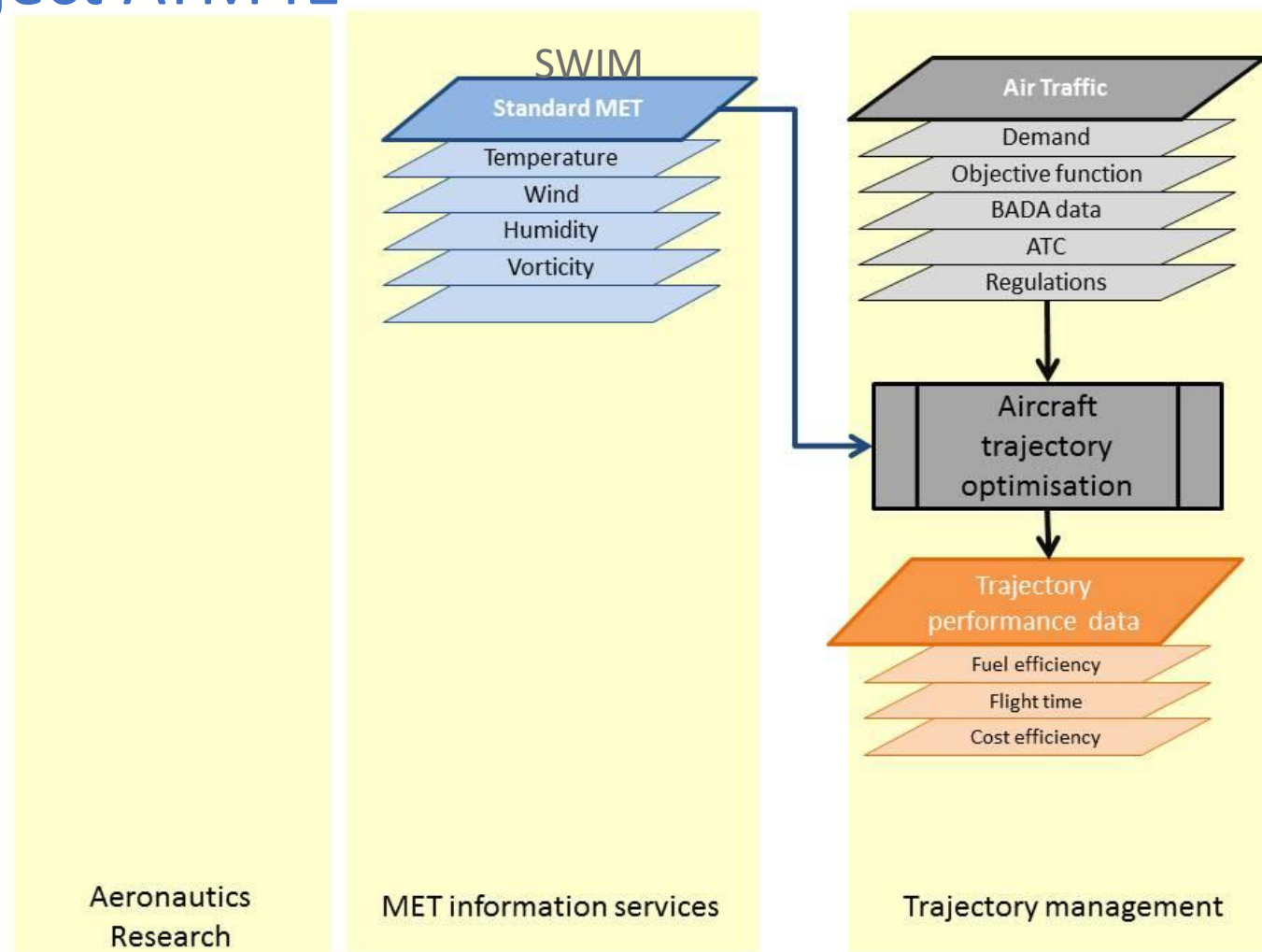


Frömming et al., 2020

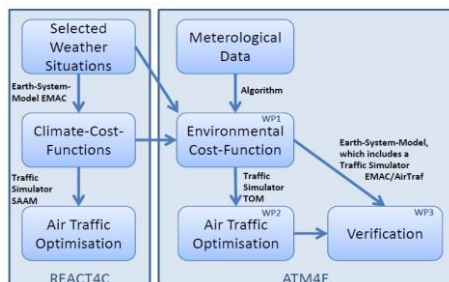


Air traffic management for environment: SESAR/H2020-Project ATM4E

Current situation



Air traffic management for environment: SESAR/H2020-Project ATM4E



Contribution of ATM4E

