



Environmentally optimized trajectories - Air Traffic Management for Environment ATM4E

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Founding Members



<http://www.atm4e.eu/>



Project ATM4E

Air Traffic Management for Environment



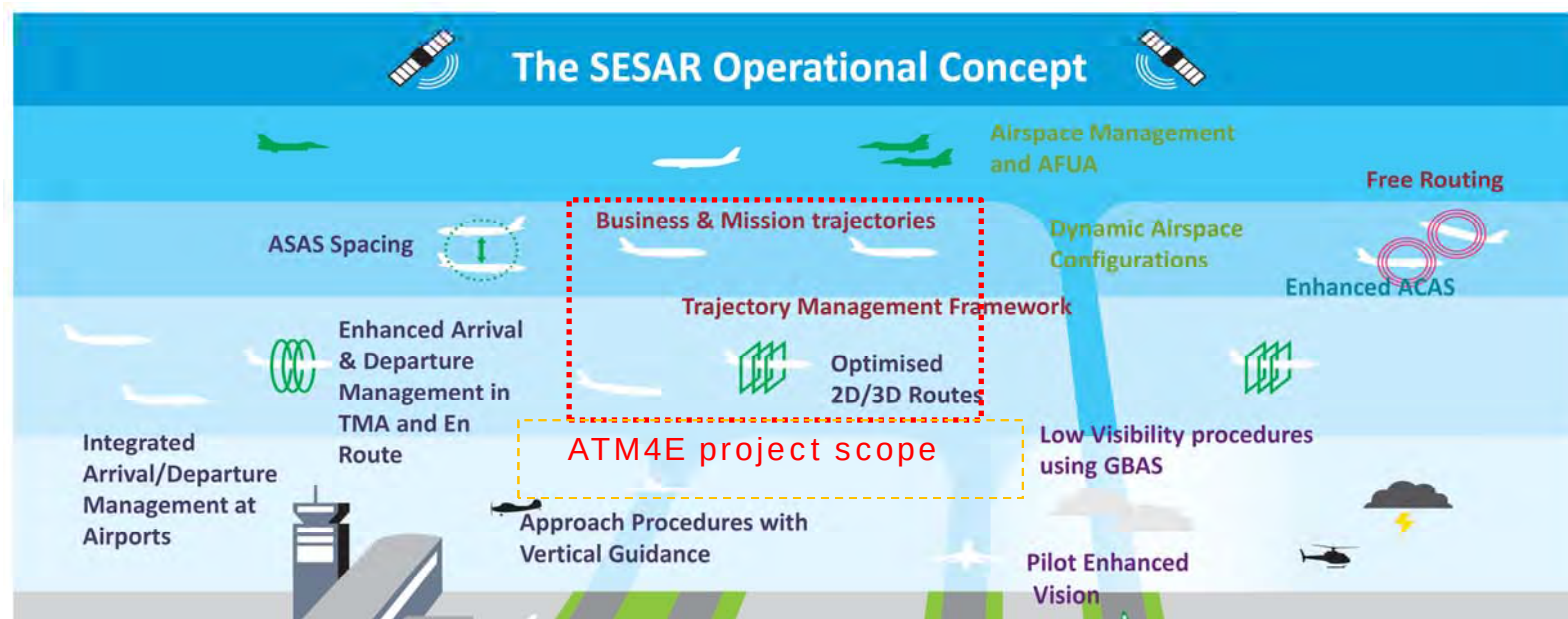
- ATM4E is an exploratory research project within **SESAR 2020** (Horizon 2020).
- **Main objective** of the ATM4E project is to explore the feasibility of a concept for environmental assessment of ATM operations working towards environmental optimisation of air traffic operations in the European airspace.
- **Duration** May 2016 – April 2018   **Budget** $\approx$ 600.000 €
- The **ATM4E Consortium** is composed of 6 participants. One large research establishment (DLR), four universities (UREAD, MMU, TUHH, TUD) and one small research company (ENVISA), constituting a well-balanced consortium with experience of previously having worked successfully together.



Positioning ATM4E

Trajectory Management Framework

- ATM4E scope can be attributed to the **Trajectory Management Framework** responsible for the planning of optimized 2D/3D routes and the processing of Business and Mission trajectories within the **SESAR Operational Concept**.
- The project addresses civil aviation only (**Business trajectory**) and focuses on commercial air transport based on scheduled flight movements.



Climate optimized routing by using climate change functions

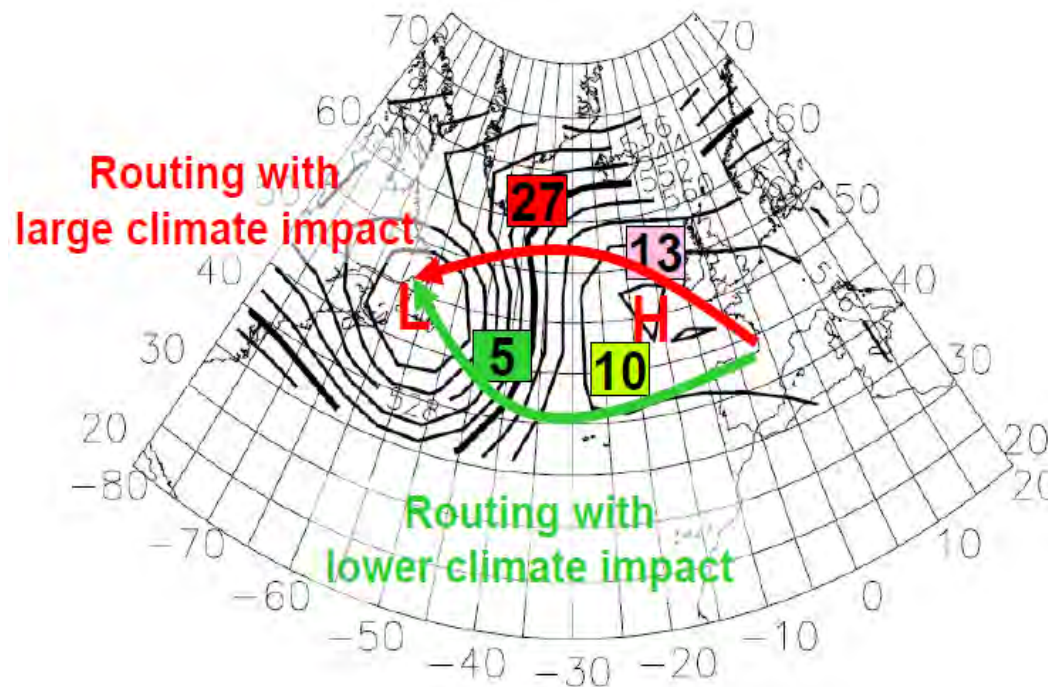
Climate change functions:

= Measure for climate impact of individual aviation emissions depending on emission location, emission altitude, and local emission time

⇒ Depending on weather situation

⇒ Aviation impacts investigated:

- Ozone, Methane + primary mode ozone, Contrails, Water vapour, CO₂



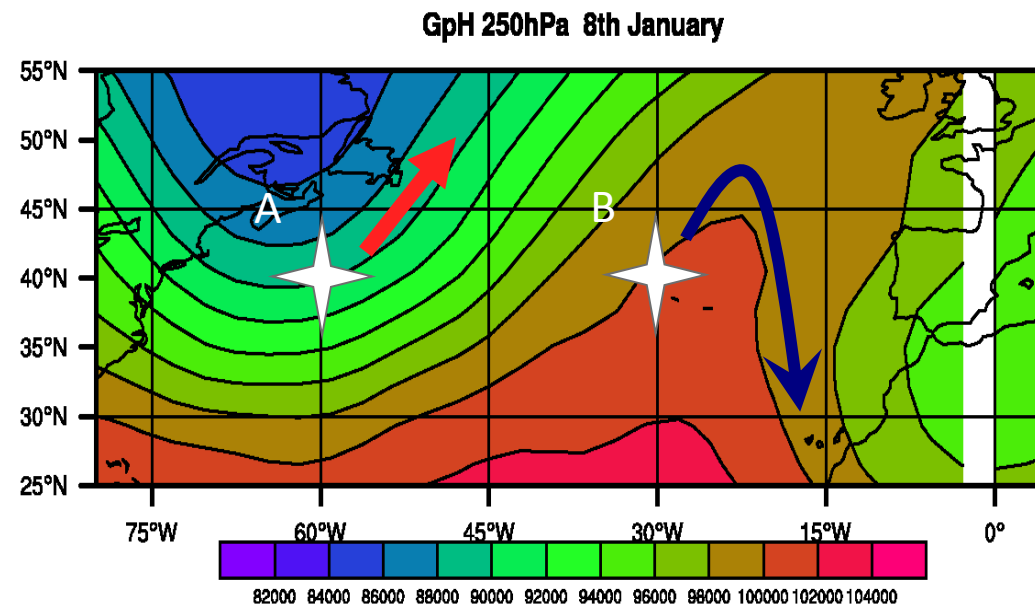
Climate cost function is given as number with units

Kelvin per kg emission



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

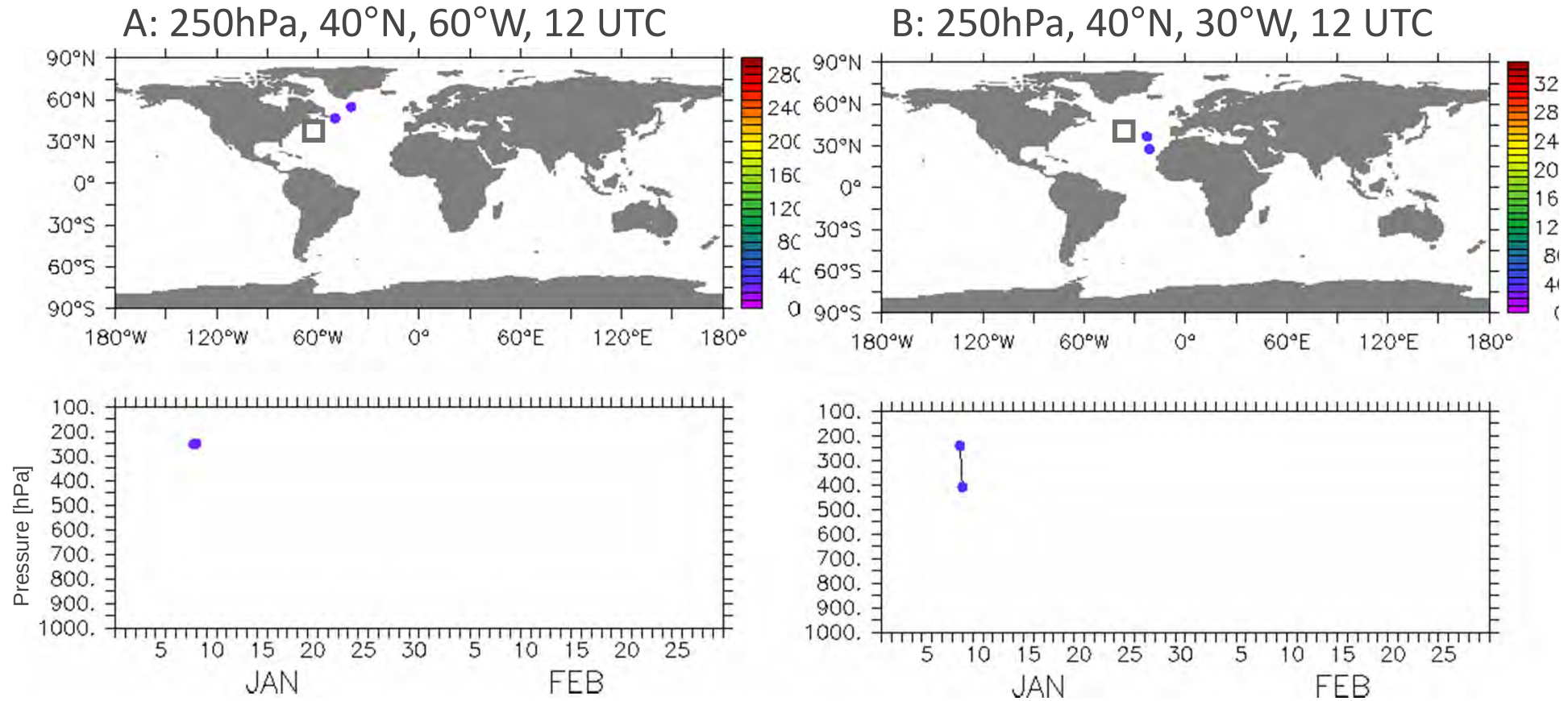
Evolution of aircraft NO_x at two different locations



What happens if an aircraft emits
 NO_x at location A compared to location B?

Frömming et al., 2011

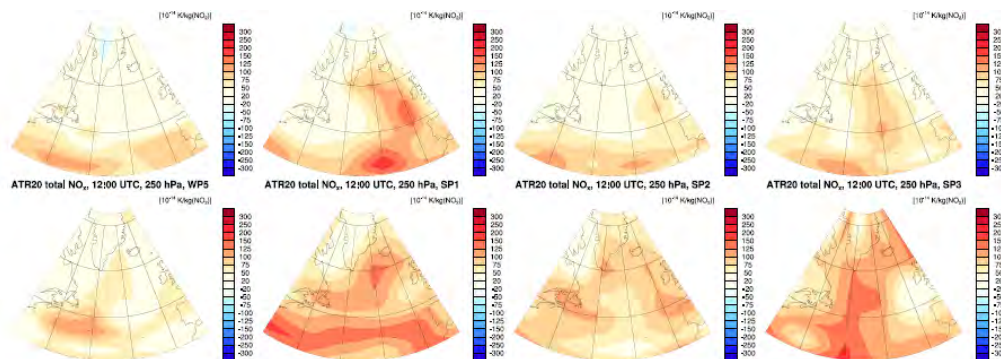
Evolution of O₃ [ppt] following a NO_x pulse



Frömming et al., 2011

Climate Change Functions

- Representative weather pattern
- 5 Winter and 3 Summer situations
- CO₂, H₂O, NO_x-emissions, and contrail-cirrus
- Climate Metric:
  - 20 Year mean temperature change after introduction of the measure (ATR20)



Frömming et al., 2016

Air Traffic

~800 flights between USA and Europe

Real air traffic taken into account

Flight simulations performed by Eurocontrol

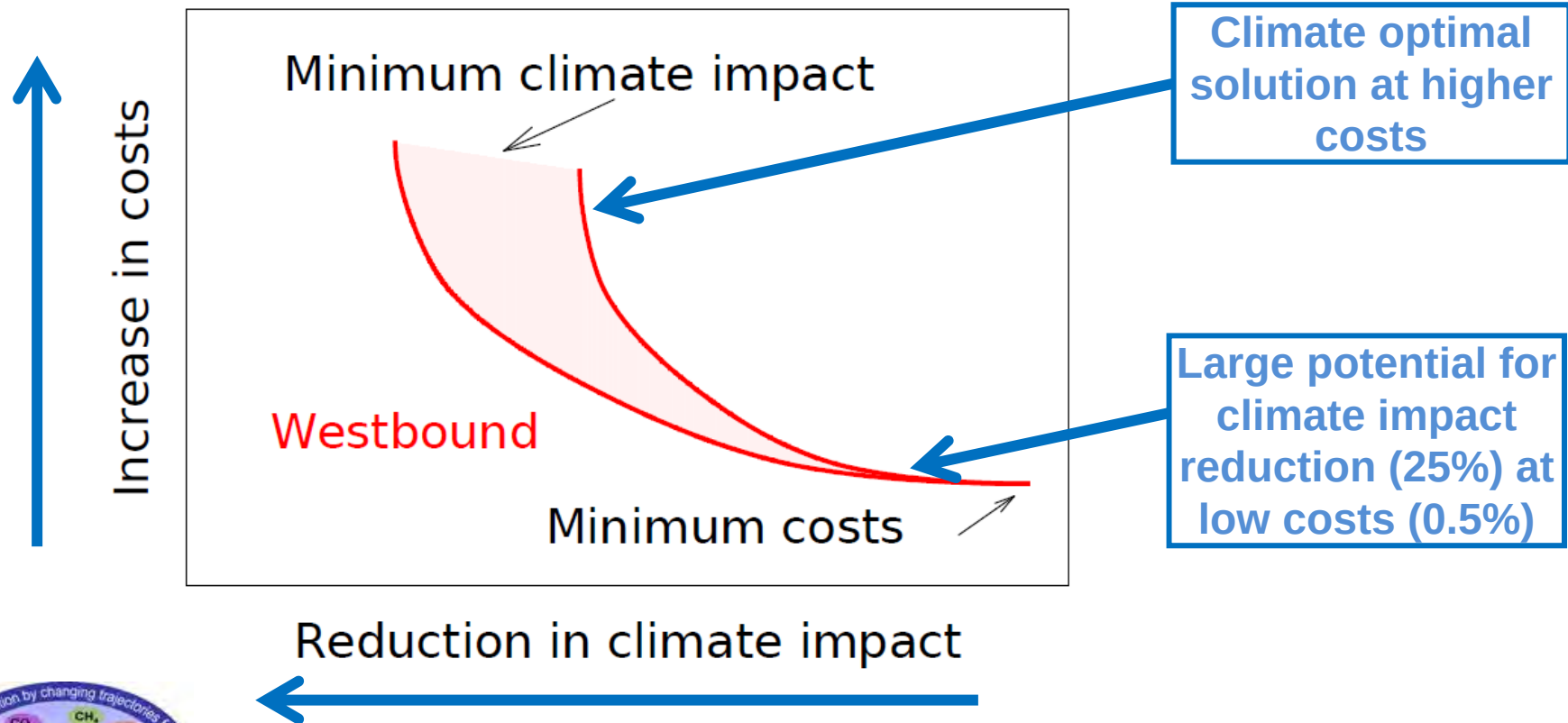
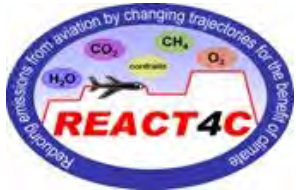
Optimisation:

- Costs: Fuel and Crew
- Climate with different metrics



Relation between costs and climate: Pareto front

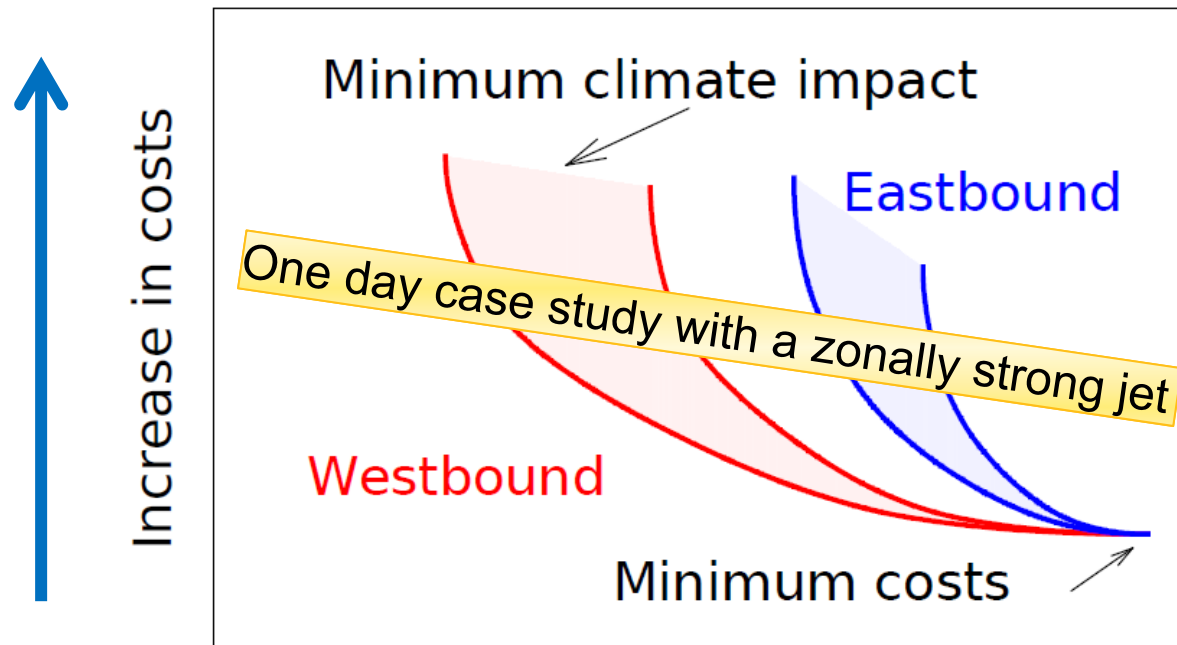
Optimal climate-cost relation



Grewe et al., 2014b

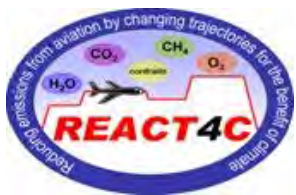
Relation between costs and climate: Pareto front

Optimal climate-cost relation



Eastbound traffic has less climate reduction potential, because it is more bound to the jet stream:

Leaving the jet stream leads to fuel and NO_x penalties

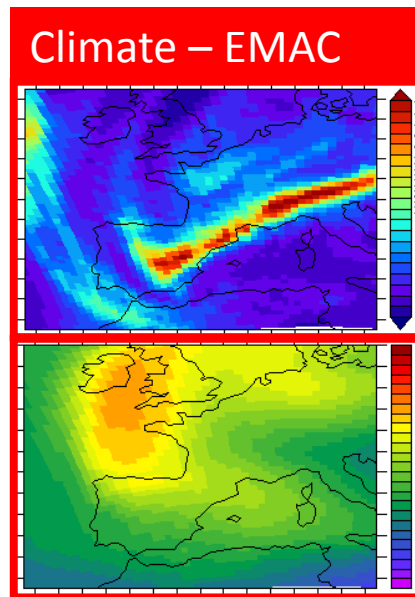
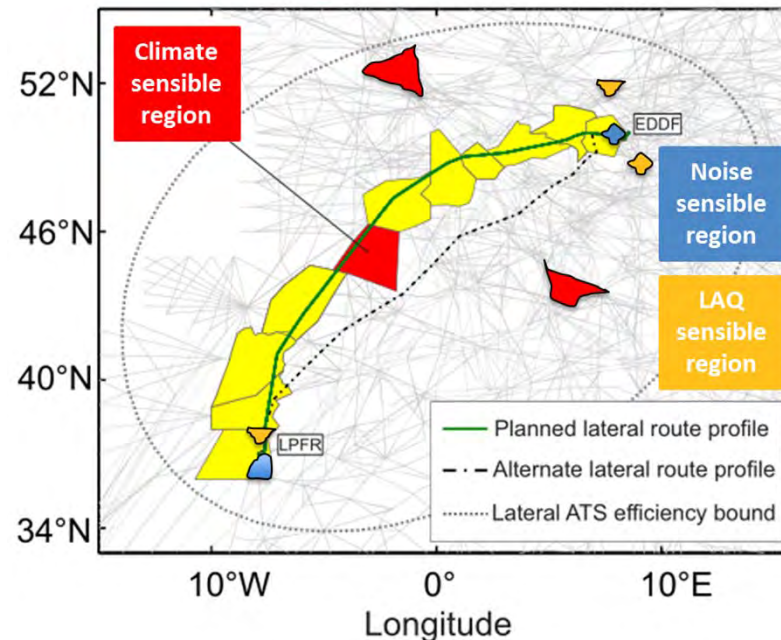


Grewe et al., 2014b

Environmental change functions

ATM4E expanded concept

During the flight the aircraft encounters individual environmental impacts described by individual **environmental change functions**.



$$\text{Impact}_{\text{env}} = \int_{\text{flight time}} R(\bar{s}(t), t, e(t)) dt,$$

Climate cost functions (CCF) [Matthes et al., 2012]
expanded to environmental change functions (ECF)

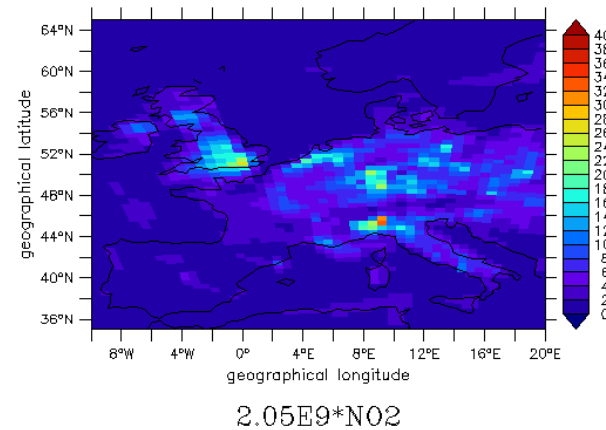
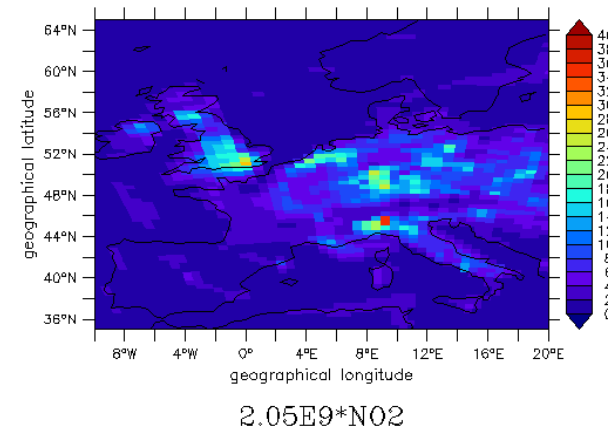
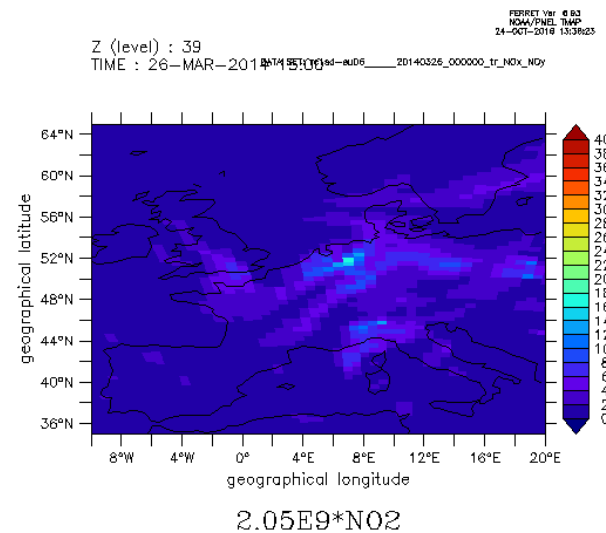
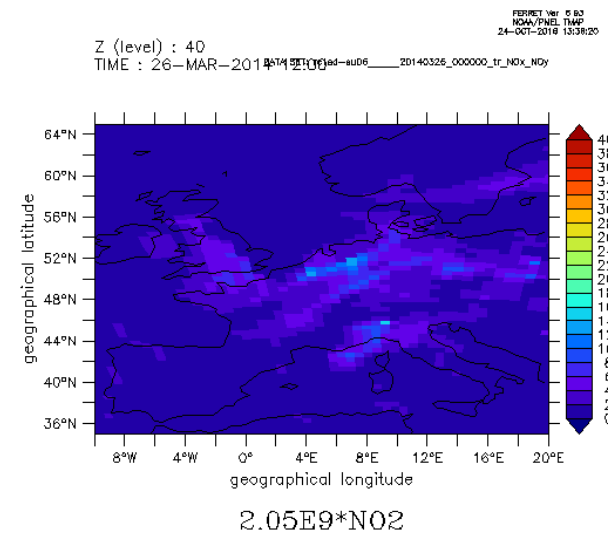
Overall change function

$$f = f(\text{Clim}, \text{LAQ}, \text{Noise}, \text{DOC})$$

$$f = \sum w_i m_i I_i + w_{\text{DOC}} I_{\text{DOC}}$$

Nitrogen oxides near the ground

NO2 concentration



Objective ATM4E

Environmentally-optimized flight planning



- The project aims at **integrating existing methodologies for assessment of the environmental impact of aviation**, in order to evaluate the implications of **environmentally-optimized flight operations** to the European ATM network, considering climate, air quality and noise impacts.
- A modelling concept for climate-optimisation which has been developed in a feasibility study for the North Atlantic **will be expanded to a multi-dimensional environmental impact assessment**, covering climate, air quality and noise.
- Different **traffic scenarios (present-day and future)** will be analysed to understand the extent to which environmentally-optimized flights that are planned and optimized based on multi-dimensional environmental criteria (assessment) would **lead to changes in air traffic flows and create challenges for ATM**.
- These findings will be used **to prepare a roadmap** compliant with SESAR2020 principles and objectives which would consider the necessary steps and actions that would need to be taken **to introduce environmentally-optimized flight operations** on a large scale in Europe.

ATM4E [ref DoA]



Interface between environmental impact and ATM via Environmental Change Functions

How to make available information on environmental impact for
flight planning.



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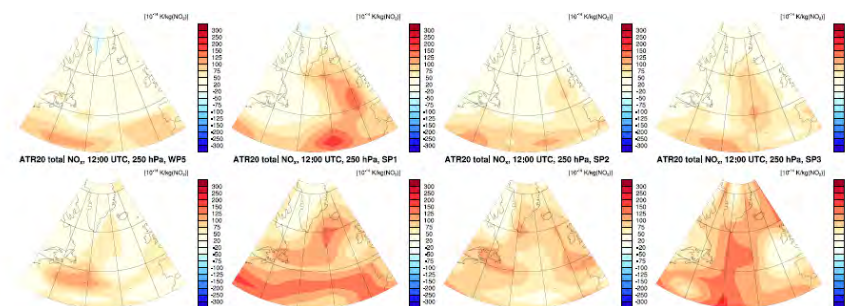
Overall Objectives and Participation



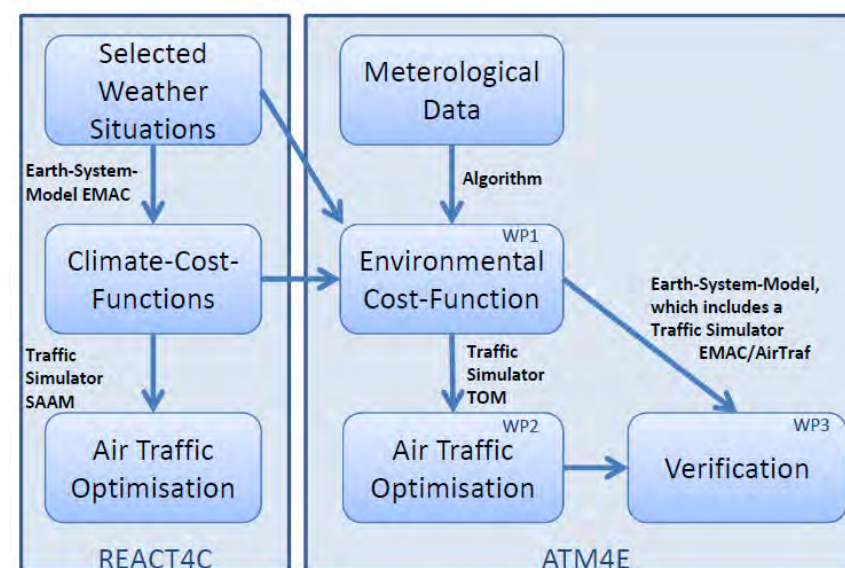
- To provide Climate Change Functions (CCF) as predictors for the climate impact of localized air traffic emissions
- To derive a reliable algorithm-based Environmental Change Functions (ECF) for use in weather prediction models to expand the environmental cost function (currently driven by climate change considerations)
- To include perceived noise annoyance and local air quality impacts
- To integrate impacts via environmental metrics considering local impacts versus global impacts

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
- Integration of **environmental impact information** via Meteorological interface to **SWIM infrastructure** (SESAR 2020) to make it available during flight planning.



Frömming et al., 2016





Environmental-optimized routing impact on ATM changes in air traffic flows

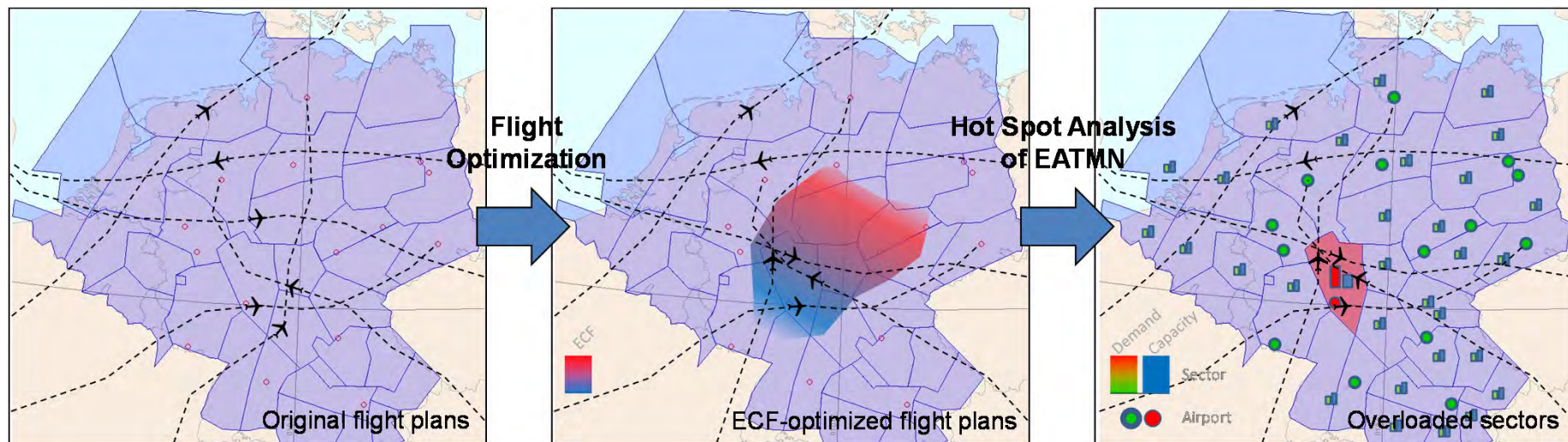


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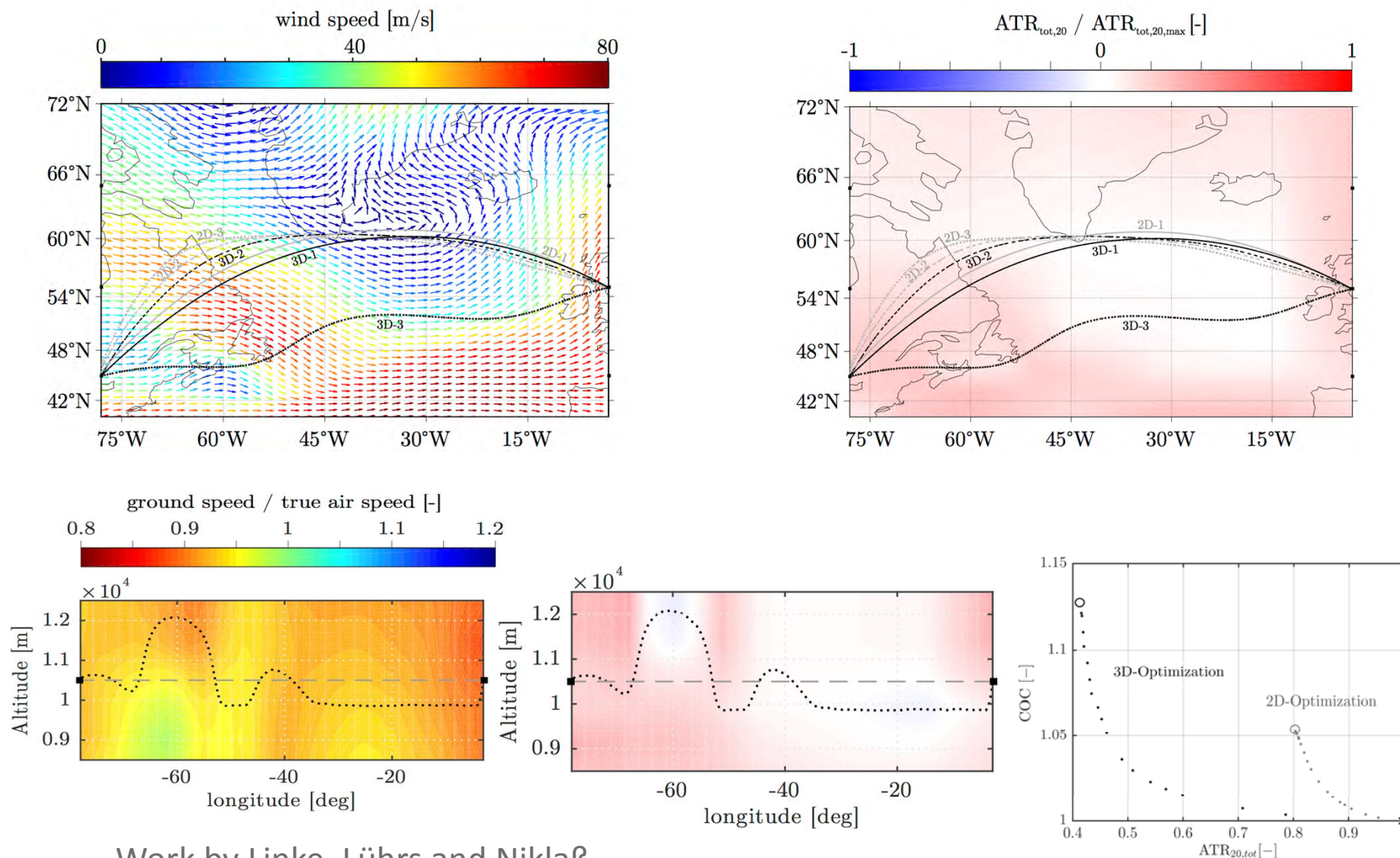


Environmental-optimized routing impact on ATM changes in air traffic flows

- To **optimize trajectories** to minimize the environmental impact of an air traffic sample in the European airspace
- To **analyze ATM network implications** (hot spots) resulting from environmental optimized routing



Trajectory Optimization Module



Work by Linke, Lührs and Niklaß



Verification of environmental benefit by due to environmental-optimized flight planning



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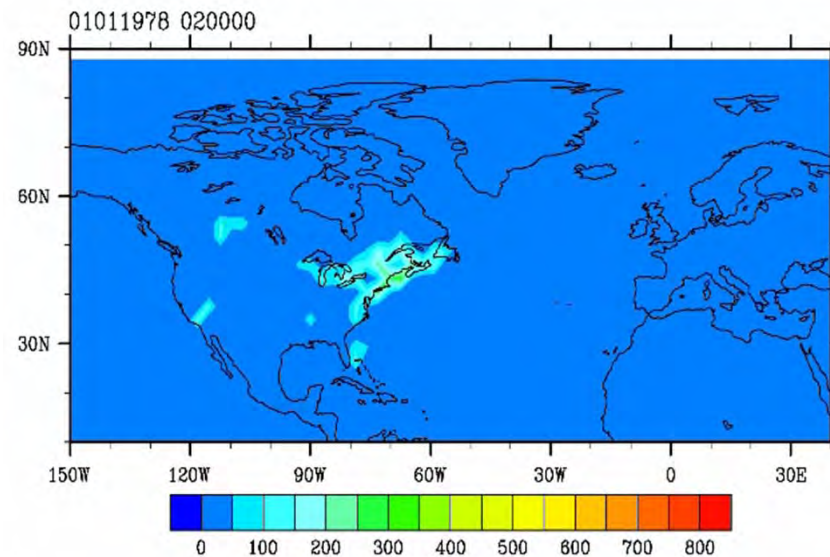
Verification of Environmental Benefit



Using comprehensive global chemistry-climate model
EMAC and routing module: AirTraf

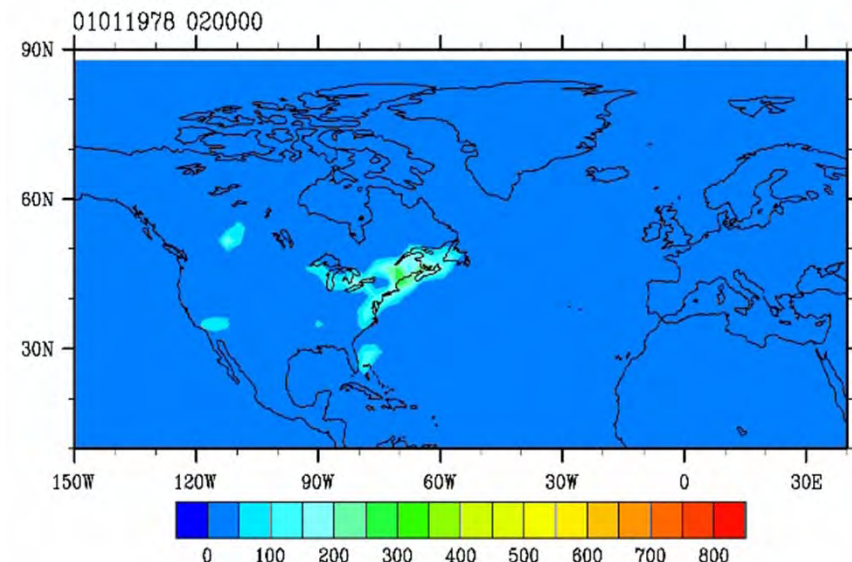
Yamashita et al., GMD, 2016.

Great circle FL330



Kg(fuel)/box/s

Time-optimal



Kg(fuel)/box/s

Atmospheric model uses algorithm based Environmental change functions.

We will focus on the European Airspace in the ATM4E project



Implementation road map Assessment & Exploitation

Intermediate implementation steps for flight planning in Europe
Roadmap with recommendations and implementation steps



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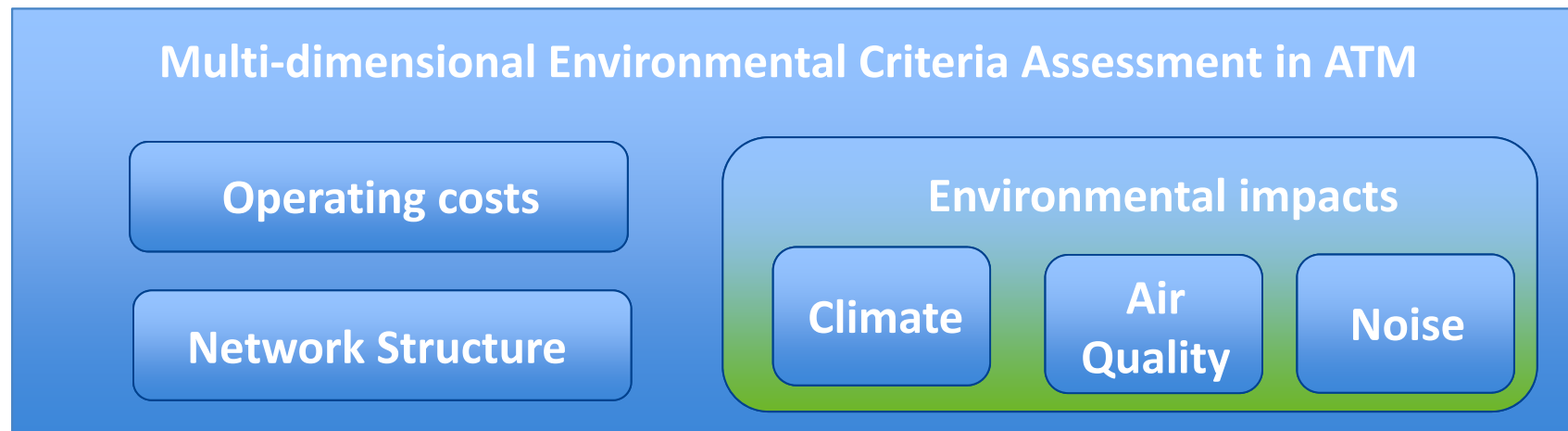


Innovation Potential

ATM4E

- ATM4E will enable **environmental assessment** of 4d aircraft trajectories with the intention to mitigate aviation environmental impact.
- ATM4E will derive **environmental impact information** based on meteorological standard parameters.

On the longer term ...



... enabling the inclusion of non-CO₂ effects in a MBM



ATM4E Overview, Sigrun Matthes, DLR

Thank you very much for your attention!



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<http://www.atm4e.eu/>



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Objectives

1) To evaluate environmental impact reduction by avoiding climate sensitive regions (e.g. contrails)

Past (REACT4C): Estimates of Climate Change Functions (CCF) for individual days

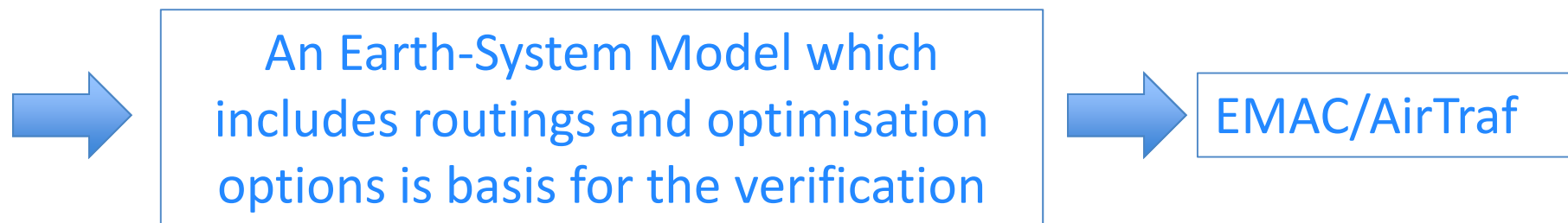
First climate estimate then routing

Future (ATM4E): Environmental impact of routings for many days

Routing and environmental impact coupled

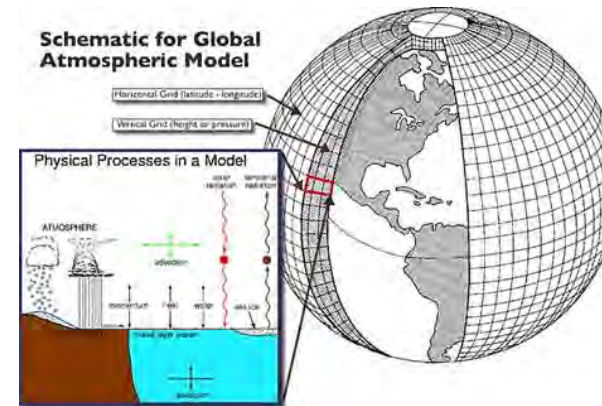
2) To verify effectiveness of algorithm based ECF with a coupled Earth-System-Model

- Algorithm based Environmental Change Functions (ECF) are simplified indications of climate sensitive regions.
- Here, we verify that they serve their purpose

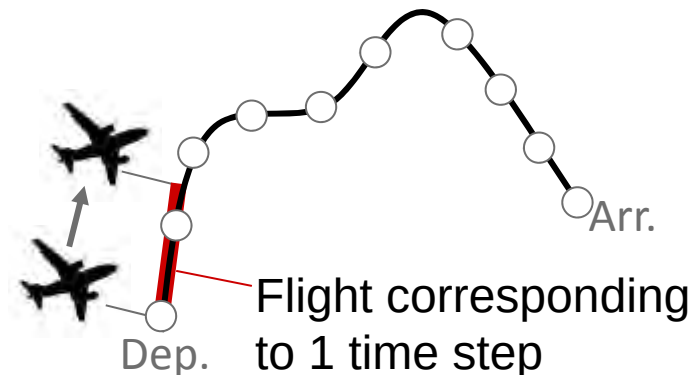


Tool: ECHAM5/MESSy Atmospheric Chemistry EMAC/AirTraf

- EMAC version with fully integrated air traffic simulator.



- AirTraf model includes a trajectory optimisation based on a genetic algorithm.



Description of EMAC/AirTraf can be found in Yamashita et al., GMD, 9, 3363-3392, doi:10.5194/gmd-9-3363-2016, 2016.