CREATE

CREATE - INNOVATIVE OPERATIONS AND CLIMATE AND WEATHER MODELS TO IMPROVE ATM RESILIENCE AND REDUCE IMPACT

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EUROPEAN PARTNERSHIP

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Partnership

1. UNIPARTH, Università degli Studi Napoli «Parthenope»
2. ARIANET srl
3. CIRA - Italian Aerospace Research Center
4. FMI - Finnish Meteorological Institute
5. ISSNOVA, Institute for Sustainable Society and Innovation
6. NLR - Netherlands Aerospace Center
7. UPC - Universitat Politecnica de Catalunya

WHAT

CREATE is a project aligned with the research topic “Environment & Meteorology for ATM”, which is part of the research area “ATM Excellent Science & Outreach” of the SESAR 2020 Exploratory Research programme (call H2020-SESAR-2019-2).

Integrate new meteorological and air quality products into ATM

- CREATE explores the capabilities of high-resolution CTMs (Chemical-Transport Models) for air quality assessment studies to test the advantages in terms of environmental impact in TMAs (Terminal Manoeuvring Areas), and on the regional and global scales to study the impact of aviation emissions onto the global chemistry.
- CREATE explores the capabilities of CTMs for air quality assessment studies.
- CREATE explores the capabilities of short-range, high-resolution weather prediction models

WHAT

CREATE is a project aligned with the research topic “Environment & Meteorology for ATM”, which is part of the research area “ATM Excellent Science & Outreach” of the SESAR 2020 Exploratory Research programme (call H2020-SESAR-2019-2).

Investigate operational changes to ATM aiming at reducing the environmental impact from aviation

- CREATE proposes new ATM concepts, taking advantage of curved approach/depart RNP procedures and advanced 4D trajectory optimisation and replanning algorithms
- The 4D trajectory optimisation and replanning concept proposed in CREATE is designed as a 4D multi-aircraft optimisation framework

The environmental impact of flight operations is studied for both en-route and TMA phases

WHAT

CREATE is a project aligned with the research topic “Environment & Meteorology for ATM”, which is part of the research area “ATM Excellent Science & Outreach” of the SESAR 2020 Exploratory Research programme (call H2020-SESAR-2019-2).

Enhance ATM efficiency

- CREATE analyses ATM vulnerabilities with respect to weather, by considering both en-route and TMA phases and the different meteorological phenomenon (heavy winds, thunderstorms, rain, low visibility conditions) and severity levels
- CREATE integrates meteorological information for the improvement of the resilience of the ATM system to local weather and global and/or long-term phenomena

A better management of consequential delays is expected

CREATE proposes three solutions

- CREATE-SOL-1: Multi-scale multi-pollutant air quality system (WAQS)
  - This solution enables the evaluation of the impact that the air traffic regulation policy options can have on the environment and climate, estimating the extent of the environmental impacts that current and future air traffic movements might have
- CREATE-SOL-2: Multi-aircraft environmentally-scored weather-resilient optimized 4D-trajectories
  - This solution aims to support the update and revision process of the reference business trajectory (RBT) in highly disrupted scenarios due to weather hazards or climate-sensitive zones, tackling (near) real-time aspects and the network and safety constraints arising in a multi-aircraft environment
- CREATE-SOL-3: CO_2 and non-CO_2 balanced Environmental Scores Module
  - The solution points to the “greenness” of aircraft trajectories related to flight and ATC sector environmental performance. Candidate trajectories are evaluated with respect to CO_2, NO_x and contrail probability formation

GLOBAL AND REGIONAL-SCALE

Emission module

- Biogenic, fires, bioaerosol
- Sea salt, desert dust
- Marine and aviation activities
- Anthropogenic activities

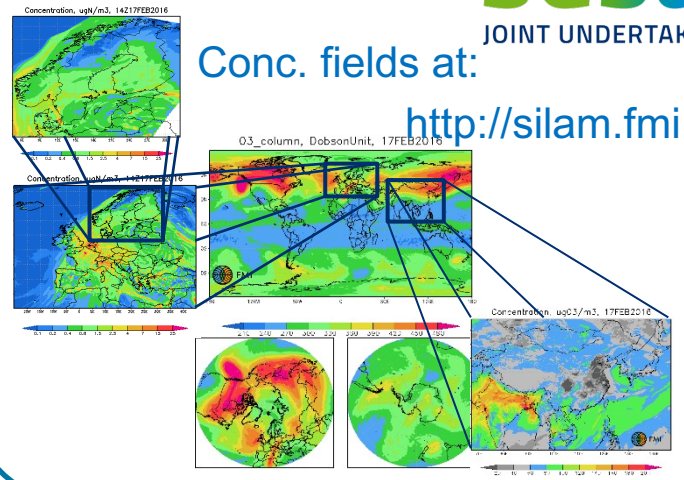
Meteo module

- **Global**: ECMWF
- **Regional**: HIRLAM, WRF
- **Climate**: ECHAM,RCA,G/RCM

SILAM

sesar JOINT UNDERTAKING

Conc. fields at:
http://silam.fmi.fi



EVALUATION
and
DATA ASSIMILATION
3D-, 4D-VAR

Online AQ monitoring

Aerobiological observations

LOCAL AND MICRO-SCALE

Meteo module

Regional IC/BC: WRF

Geo data

NWP, EWP module

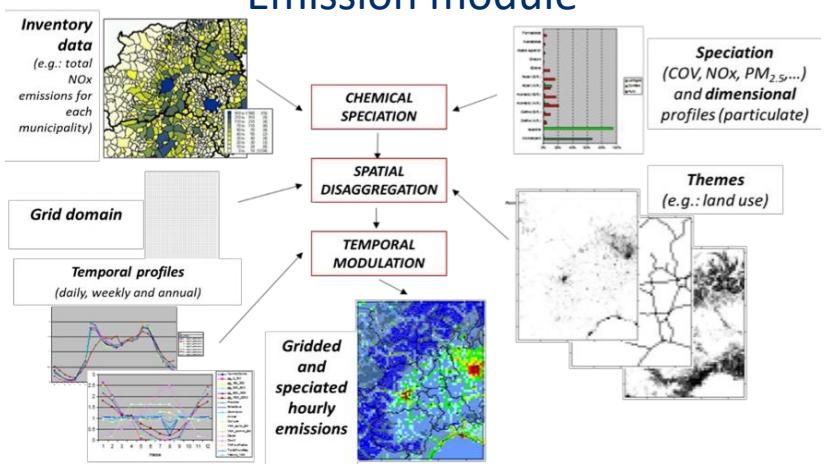
Prognostic interface

FARM

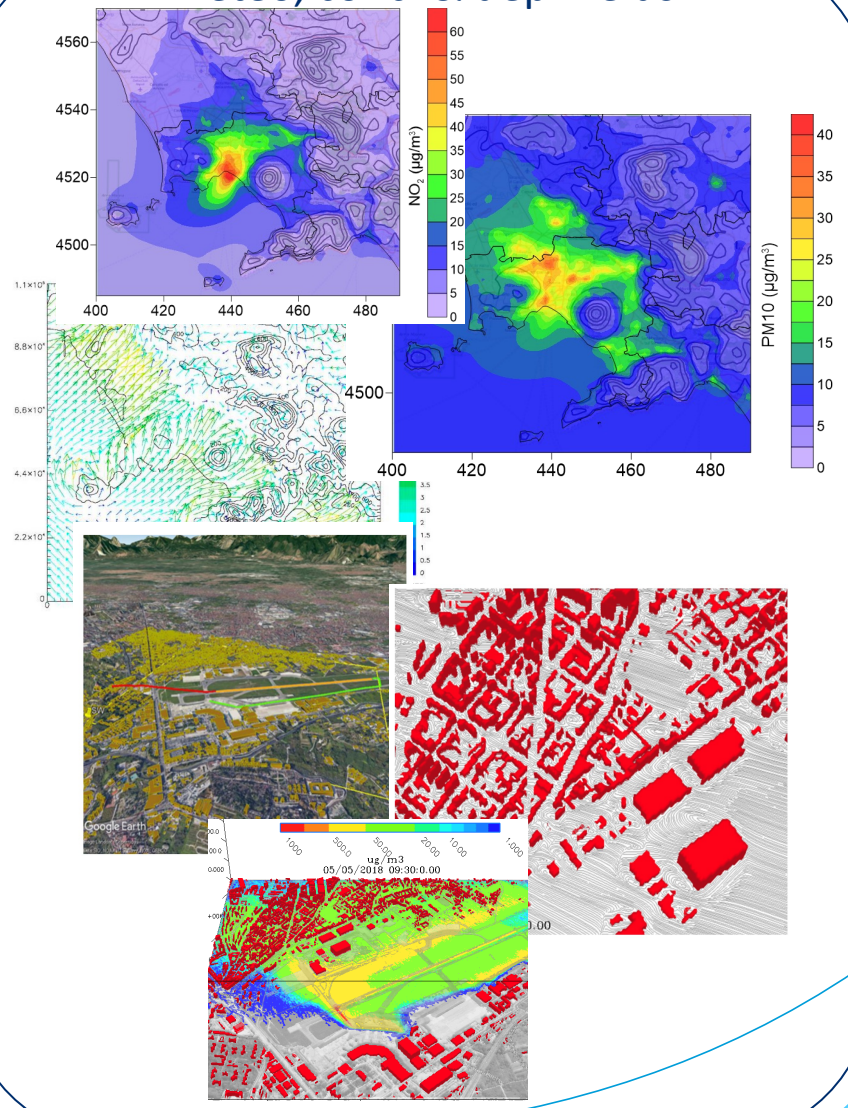
Spray

Micro-Spray

Emission module



Meteo, conc. & dep. fields



Regional scale emission – all sectors

CREATE-SOL-1: exploring the capabilities of WAQS for air quality assessment studies, an example of application for the Capodichino TMA

	CO/10 t/year	NMVOC t/year	NH3 t/year	NOX t/year	PM2.5 t/year	PM10 t/year	SO2 t/year	DIOX g/year	IPA kg/year
01-Combustion in energy and transformation industries	71	93	8	1257	13	18	13	0	0
02-Non-industrial combustion plants	13131	16165	151	4324	9917	10028	410	11	5389
03-Combustion in manufacturing industry	118	77	25	2603	173	206	744	0	2
04-Production processes	0	2772	0	0	199	333	243	0	46
05-Extr. and distr. of fossil fuels and geothermal energy	0	1071	0	0	0	0	0	0	0
06-Solvent and other product use	0	23046	0	0	0	0	0	0	1
07-Road transport	4163	11357	552	32052	3245	9140	31	1	212
08-Other mobile sources and machinery	1174	2640	1	13891	699	700	769	0	21
09-Waste treatment and disposal	168	376	146	101	70	81	19	0	207
10-Agriculture	27	52	17731	672	520	1922	0	0	0
11-Other sources	316	499	39	163	489	539	23	4	3460
Airports	24	27	0	1407	13	13	71	0	0
TOTAL	19193	58175	18653	55062	15324	22967	2252	16	9337

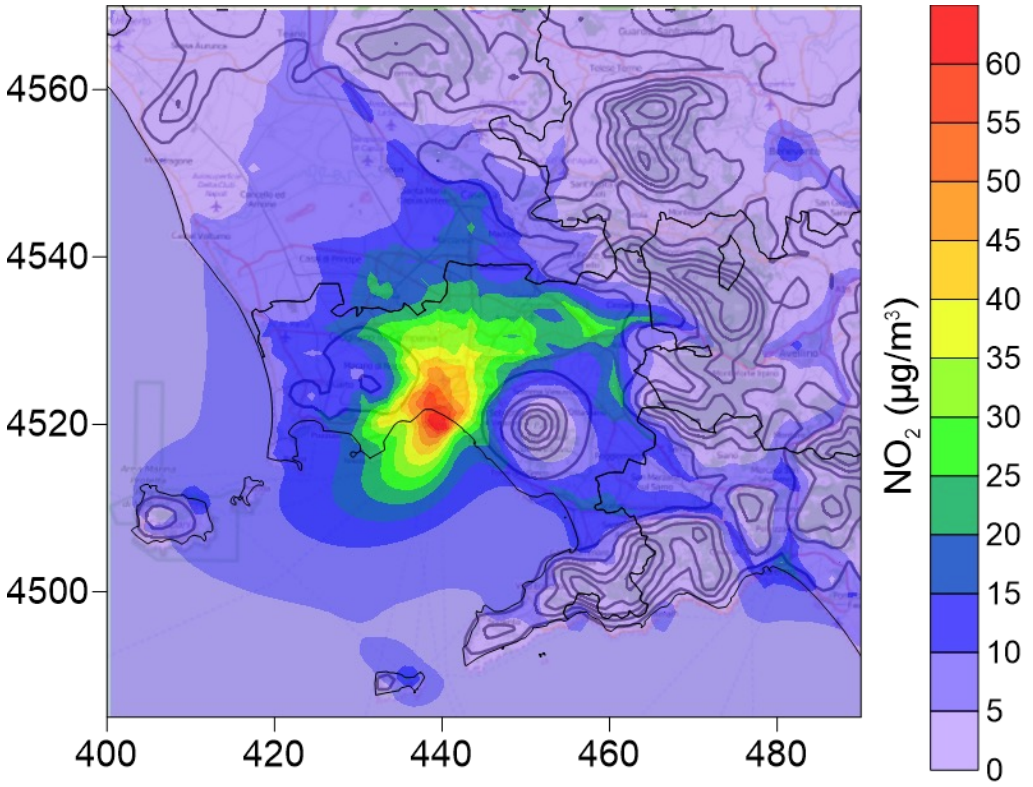
	CO/10 t/year	NMVOC t/year	NH3 t/year	NOX t/year	PM2.5 t/year	PM10 t/year	SO2 t/year	DIOX g/year	IPA kg/year
01-Combustion in energy and transformation industries	0%	0%	0%	2%	0%	0%	1%	0%	0%
02-Non-industrial combustion plants	68%	28%	1%	8%	65%	44%	18%	65%	58%
03-Combustion in manufacturing industry	1%	0%	0%	5%	1%	1%	33%	1%	0%
04-Production processes	0%	5%	0%	0%	1%	1%	11%	0%	0%
05-Extr. and distr. of fossil fuels and geothermal energy	0%	2%	0%	0%	0%	0%	0%	0%	0%
06-Solvent and other product use	0%	40%	0%	0%	0%	0%	0%	0%	0%
07-Road transport	22%	20%	3%	58%	21%	40%	1%	8%	2%
08-Other mobile sources and machinery	6%	5%	0%	25%	5%	3%	34%	0%	0%
09-Waste treatment and disposal	1%	1%	1%	0%	0%	0%	1%	1%	2%
10-Agriculture	0%	0%	95%	1%	3%	8%	0%	0%	0%
11-Other sources	2%	1%	0%	0%	3%	2%	1%	25%	37%

Comparison of airport emissions with other emissions by sectors in the Campania region in 2018

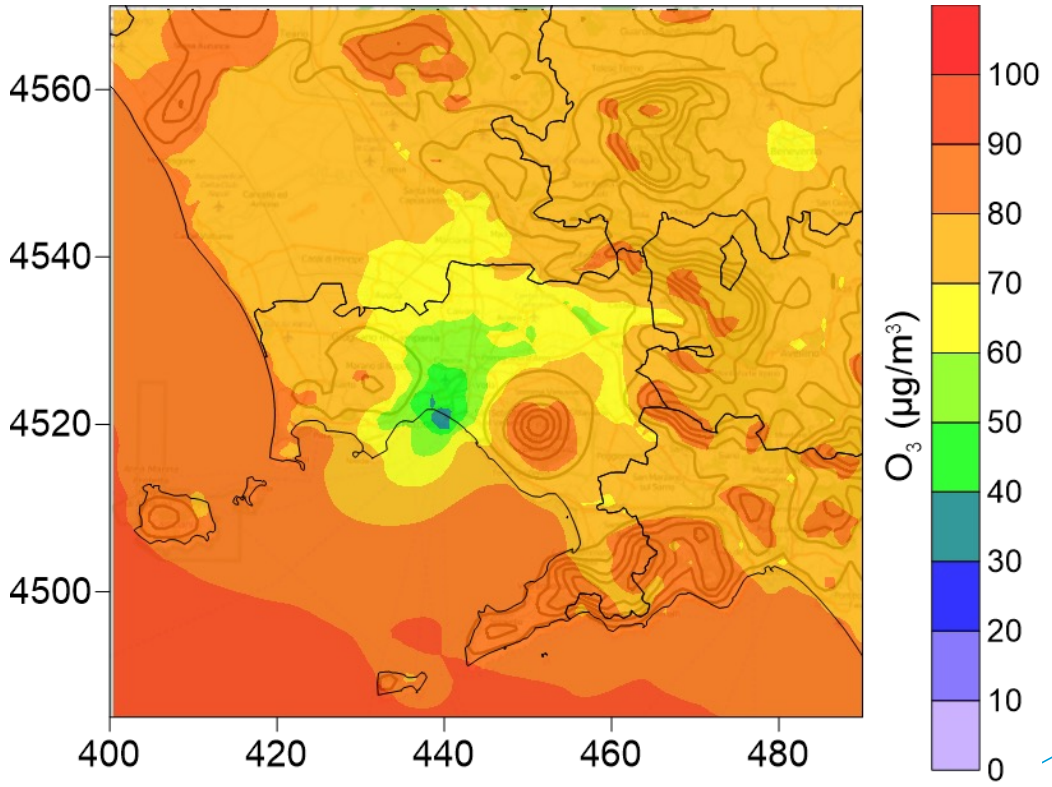
Yearly mean concentrations – all emissions

CREATE-SOL-1: exploring the capabilities of WAQS for air quality assessment studies, an example of application for the Capodichino TMA

NO_2: yearly mean concentration



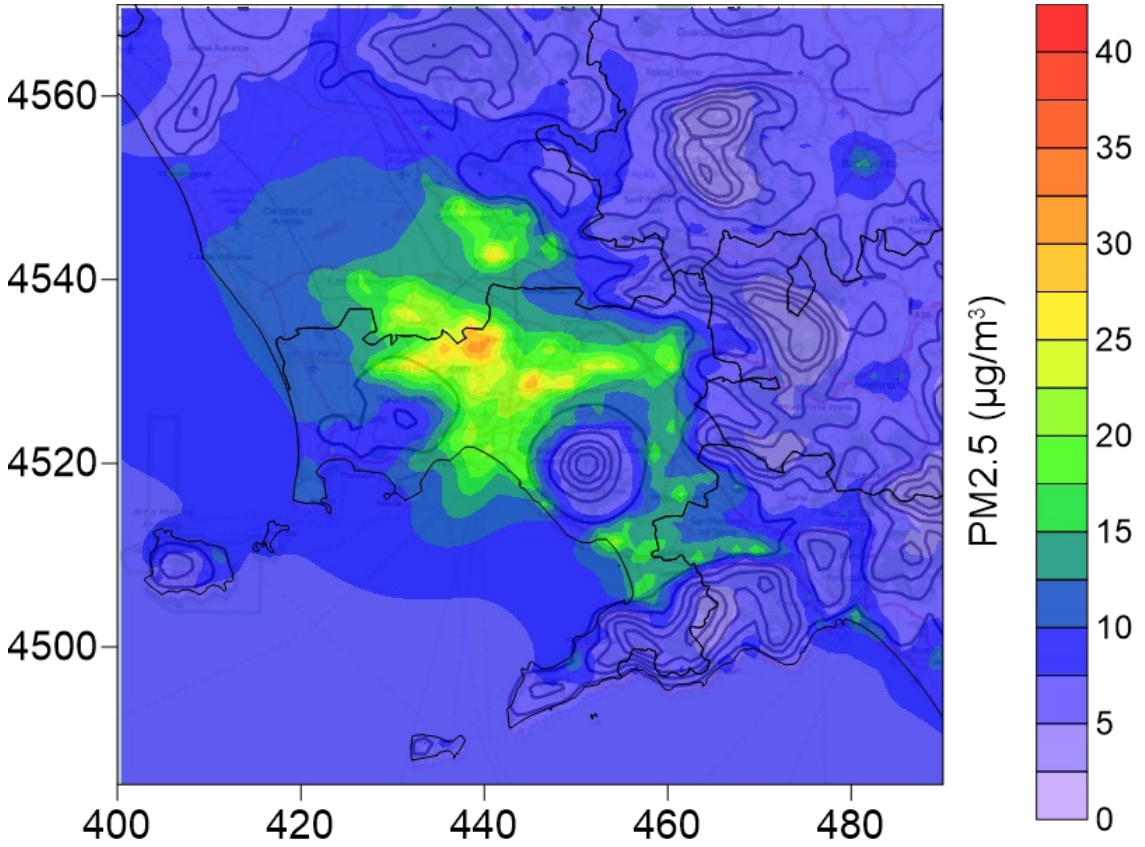
O_3: yearly mean concentration



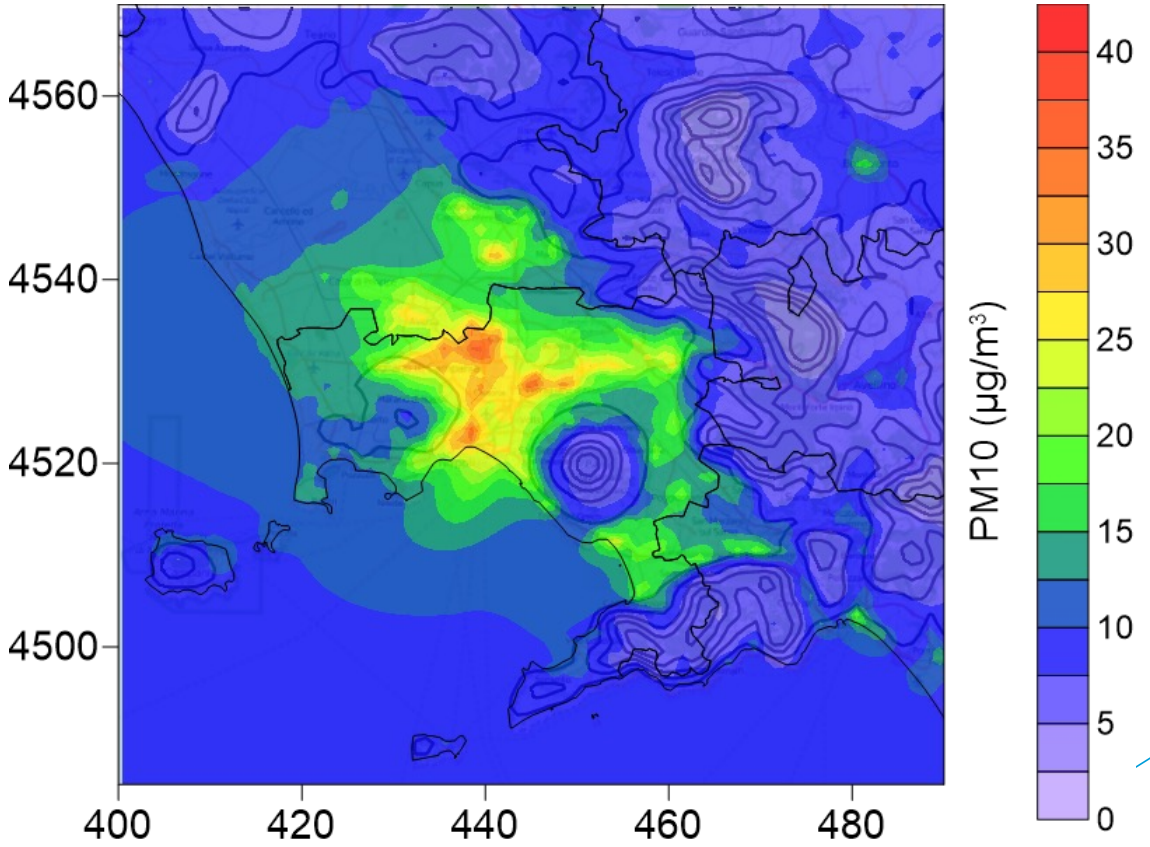
Yearly mean concentrations – all emissions

CREATE-SOL-1: exploring the capabilities of WAQS for air quality assessment studies, an example of application for the Capodichino TMA

$PM_{2.5}$: yearly mean concentration



PM_{10}: yearly mean concentration



Airport and air traffic contribution

CREATE-SOL-1: exploring the capabilities of WAQS for air quality assessment studies, an example of application for the Capodichino TMA

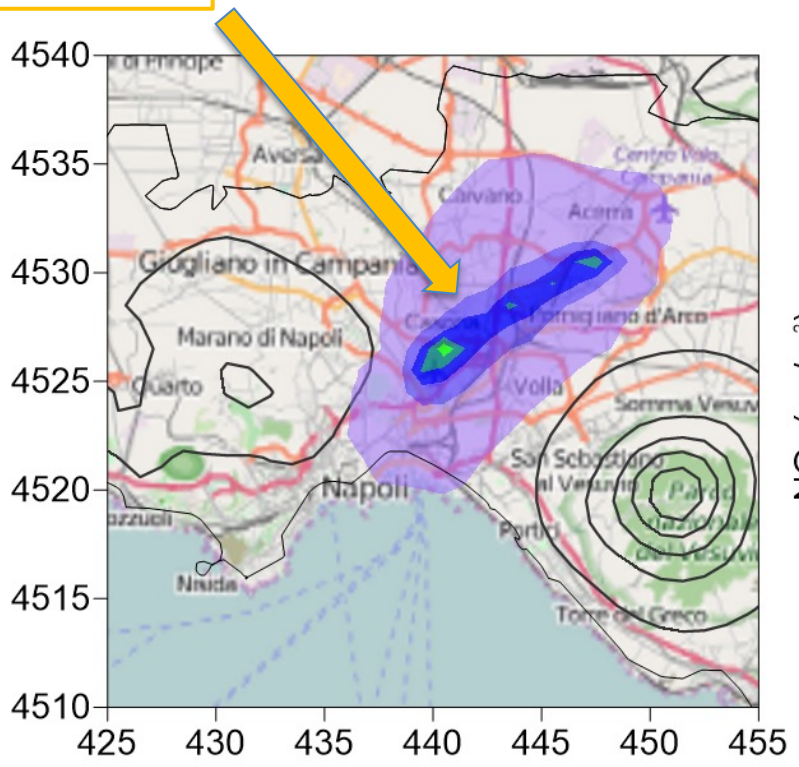
Takeoff-landing plume towards Acerra-Pomigliano

Year 2018

values > 1 µg/m^3 nearby the airport and under the landing/takeoff trajectories

NO_2

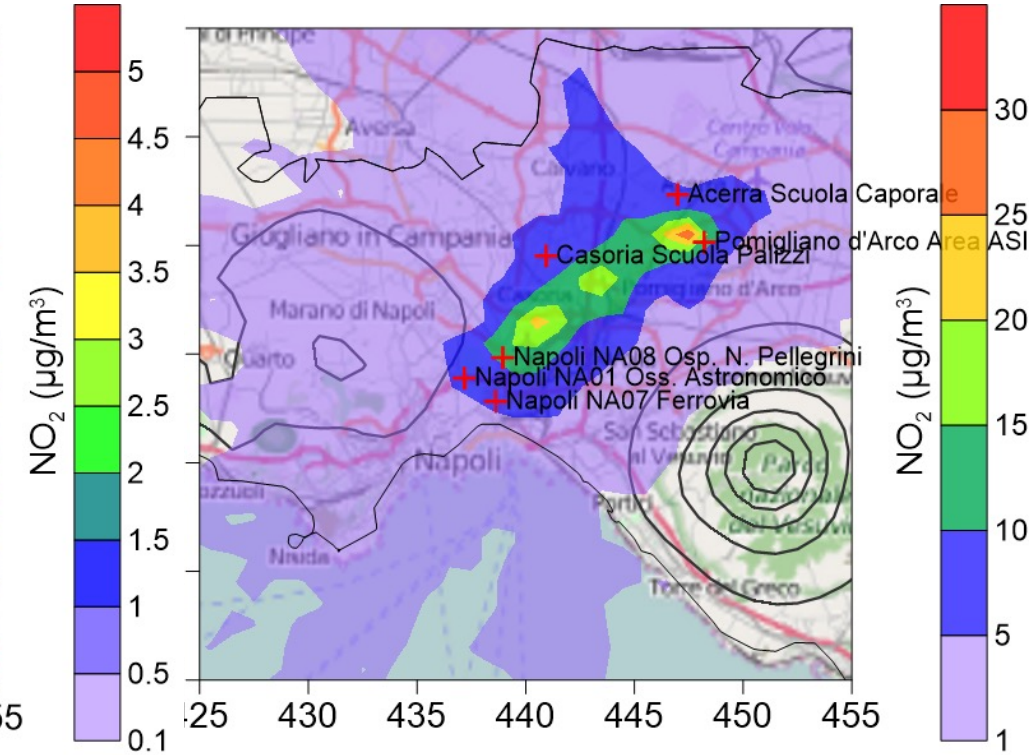
mean



values > 1 µg/m^3 nearby the airport and under the landing/takeoff trajectories

hourly maximum

Hourly max. reaching 20-30 µg/m^3

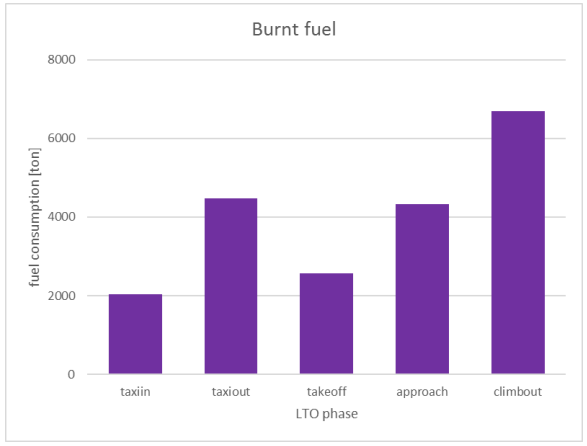


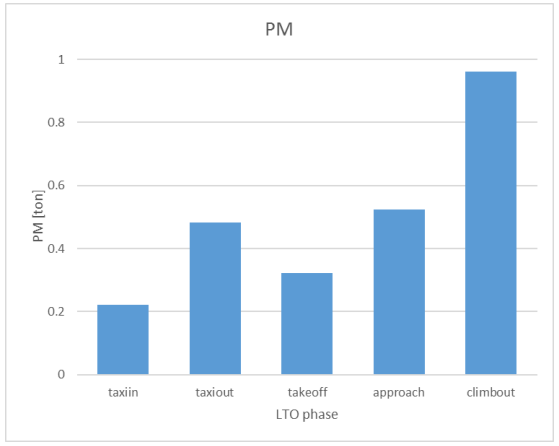
Hourly max. reaching 20-30 µg/m^3

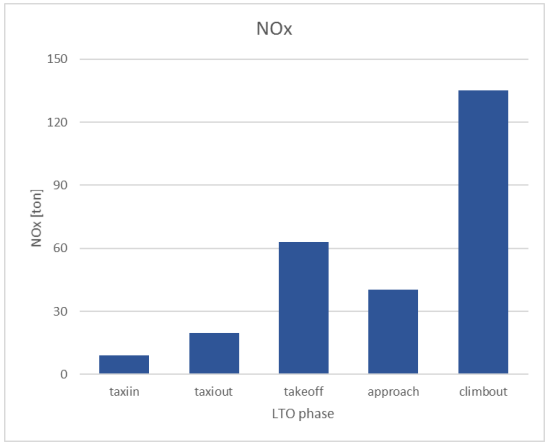
Detailed local scale emission – aviation

CREATE-SOL-1: exploring the capabilities of WAQS for air quality assessment studies, an example of application for the Capodichino TMA - detailed estimation of the airport emissions

- Input data: flight register from/to Napoli Capodichino (LIRN) in 2018. (Aircraft type, number and model of engines, specific time in mode)
- Methodology : AEM Kernel emission calculation, by each LTO phase
- Aggregated emission results by phase:

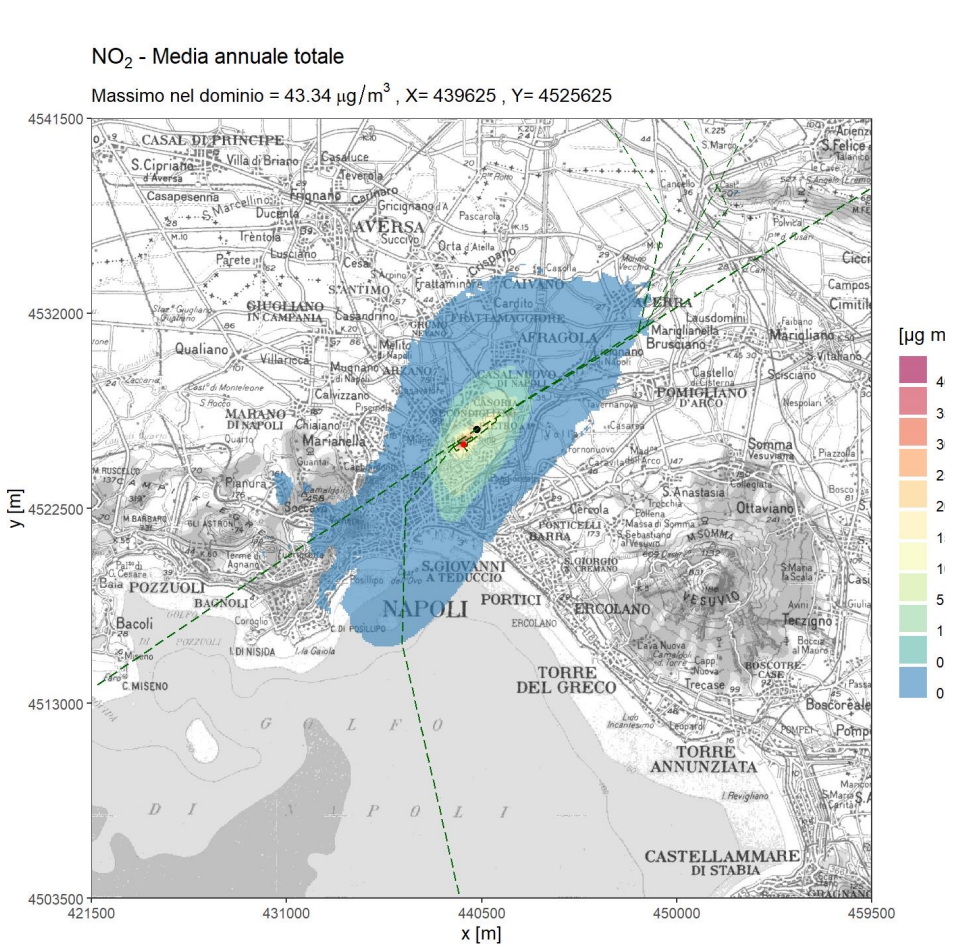


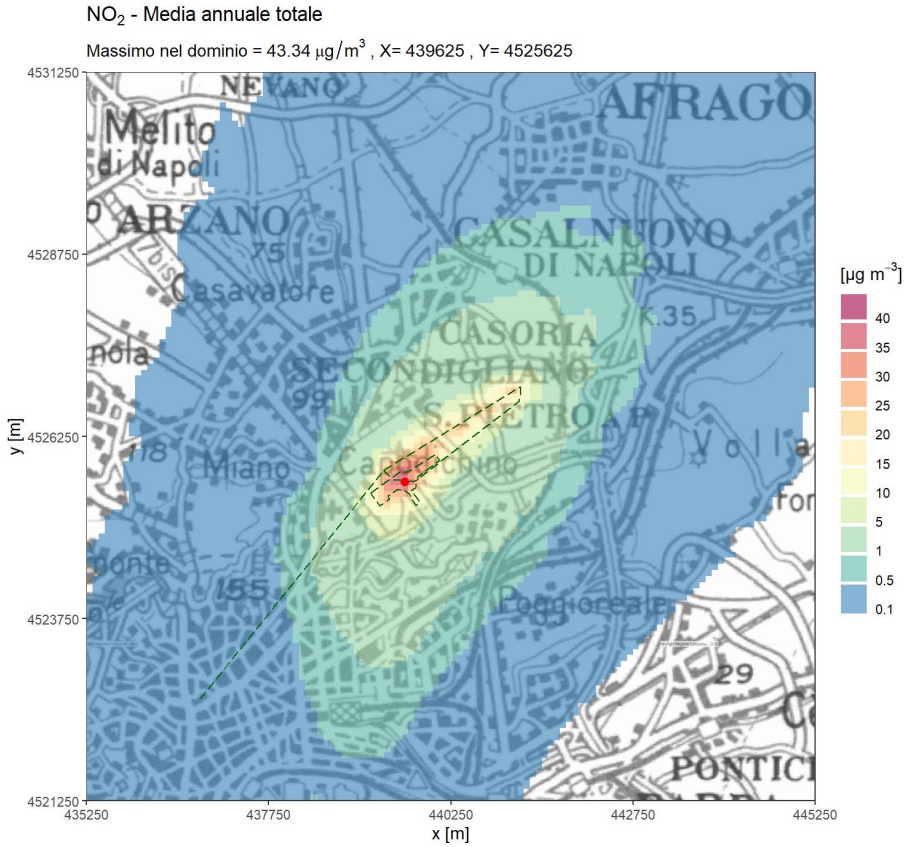




Detailed simulation of the airport emissions - impact

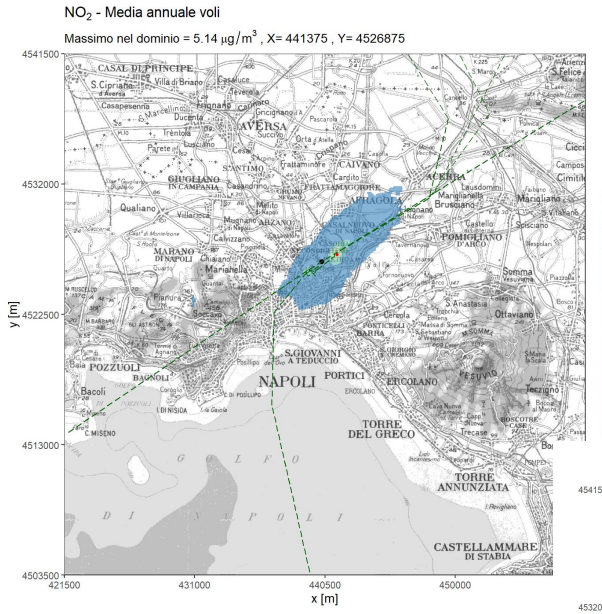
Results - NO_2 concentrations, yearly average, all activities



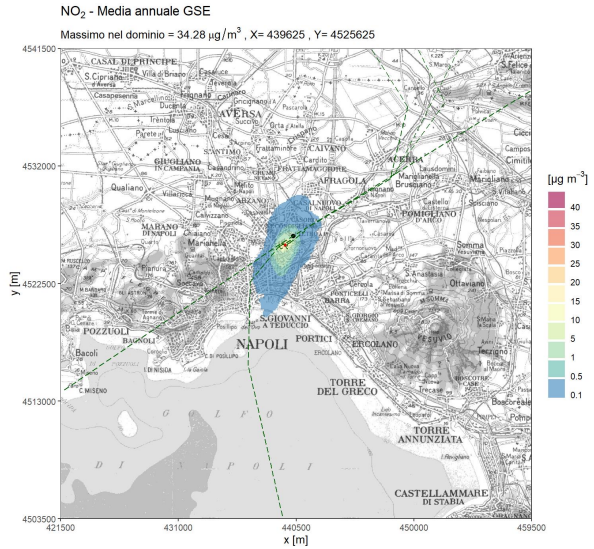


Detailed simulation of the airport emissions - impact

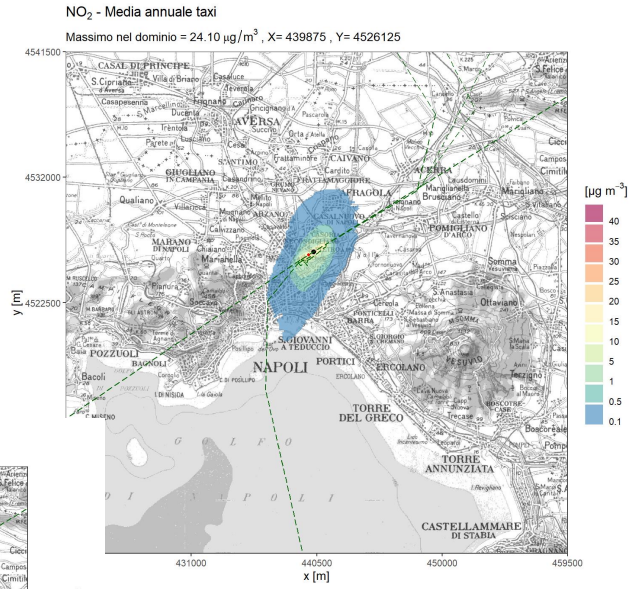
NO_2 concentration contributions by phase



LTO and Taxi



GSE



Remarks

- Emission from the aviation sector usually represent a minor fraction, al least for the case analyzed in this project
- Aviation emissions mainly affect air quality in areas nearby the airport (<2-3 km)
- NO_2 shows the largest concentration impact, ozone depletion prevails nearby the airport
- Aviation contribution is usually not detectable from urban air quality networks
- High episodic concentrations can occur in the vicinity of the airport
- Microscale concentration over short time periods (<1h) should be investigated by obstacle resolving modelling and short time measurements (tomorrow presentation)

The CREATE ConOps framework

CREATE-SOL-2: Multi-aircraft environmentally-scored weather-resilient optimized 4D-trajectories

Within CREATE-SOL-2 a concept of operations (ConOps), related to the trajectory optimisation framework, has been designed, addressing the integration of various elements:

a) multiple aircraft considered in the generation of 4D optimised trajectories;

b) Numerical Weather Prediction (NWP) and Ensemble Weather Forecasting (EWF) used for tactical trajectory replanning by predicting weather scenarios a few hours into the future of a given flight;

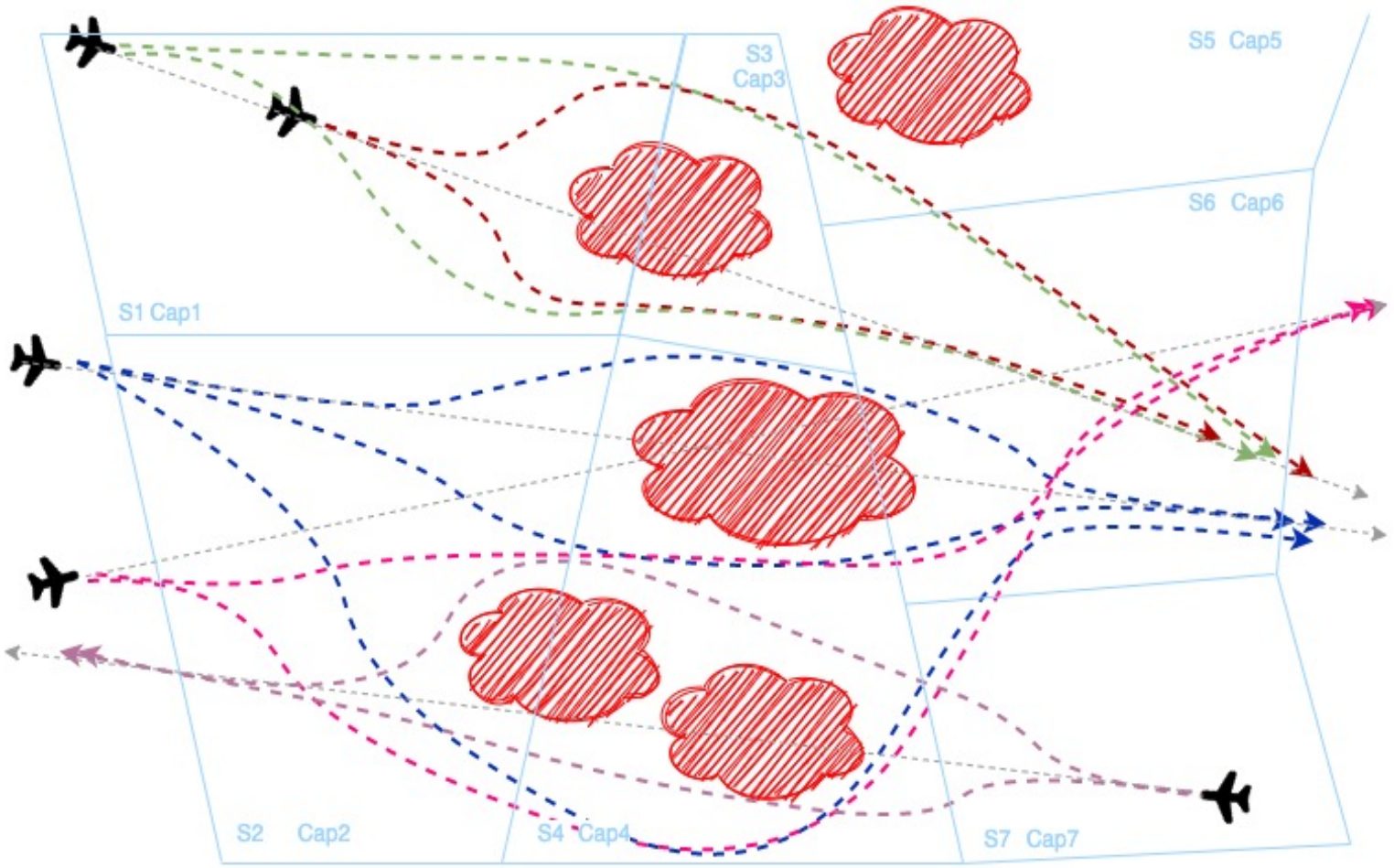
c) implementing an environmental-score assessment for all proposed candidate routes in the system;

d) Air traffic control (ATC) driven demand-capacity balancing (DCB) decision-making process to select overall optimum of the proposed trajectories within a use-case.

Demos for CREATE-SOL-2 have been applied for both en-route and TMA use-cases

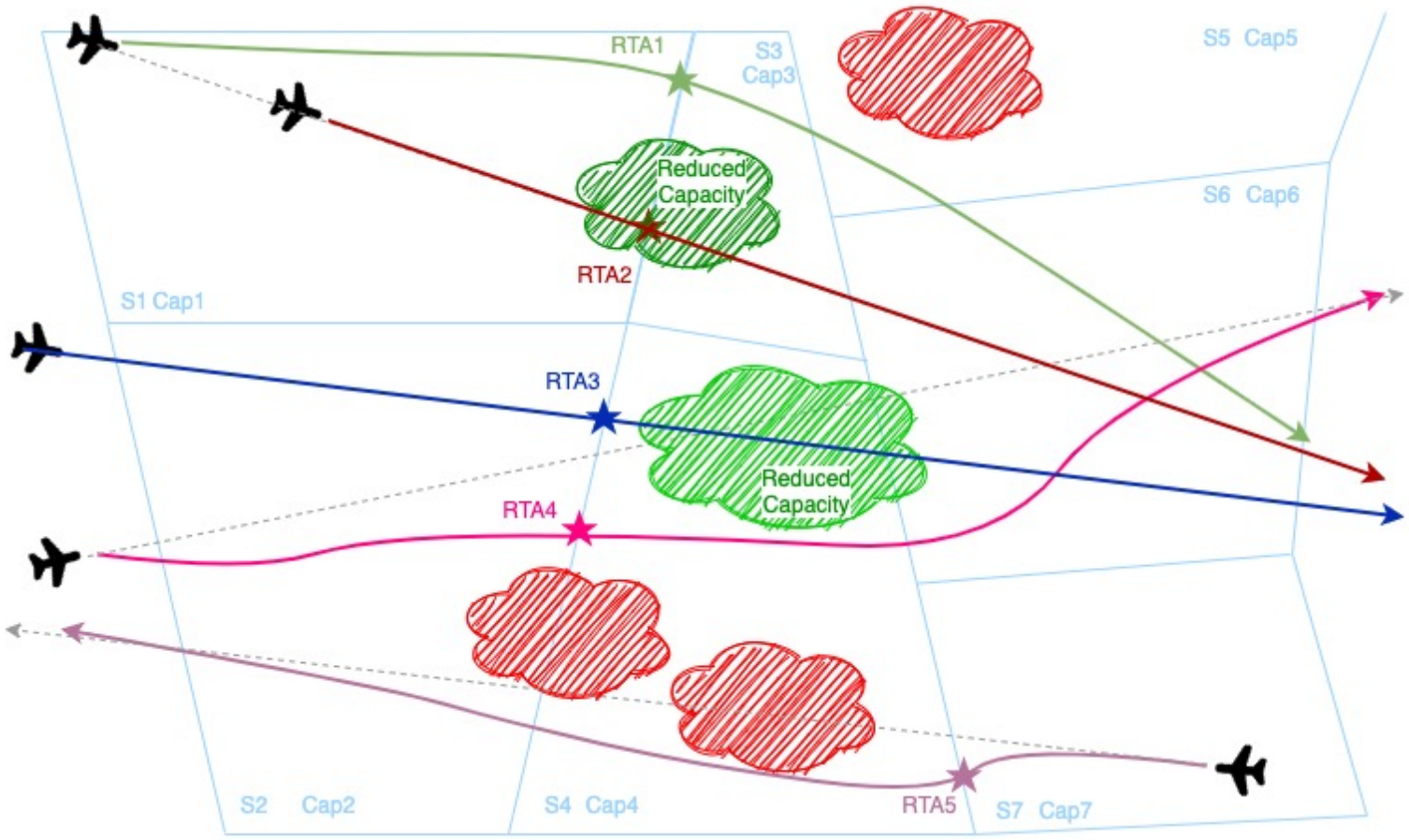
Scenario sketch

CREATE-SOL-2: Multi-aircraft environmentally-scored weather-resilient optimized 4D-trajectories



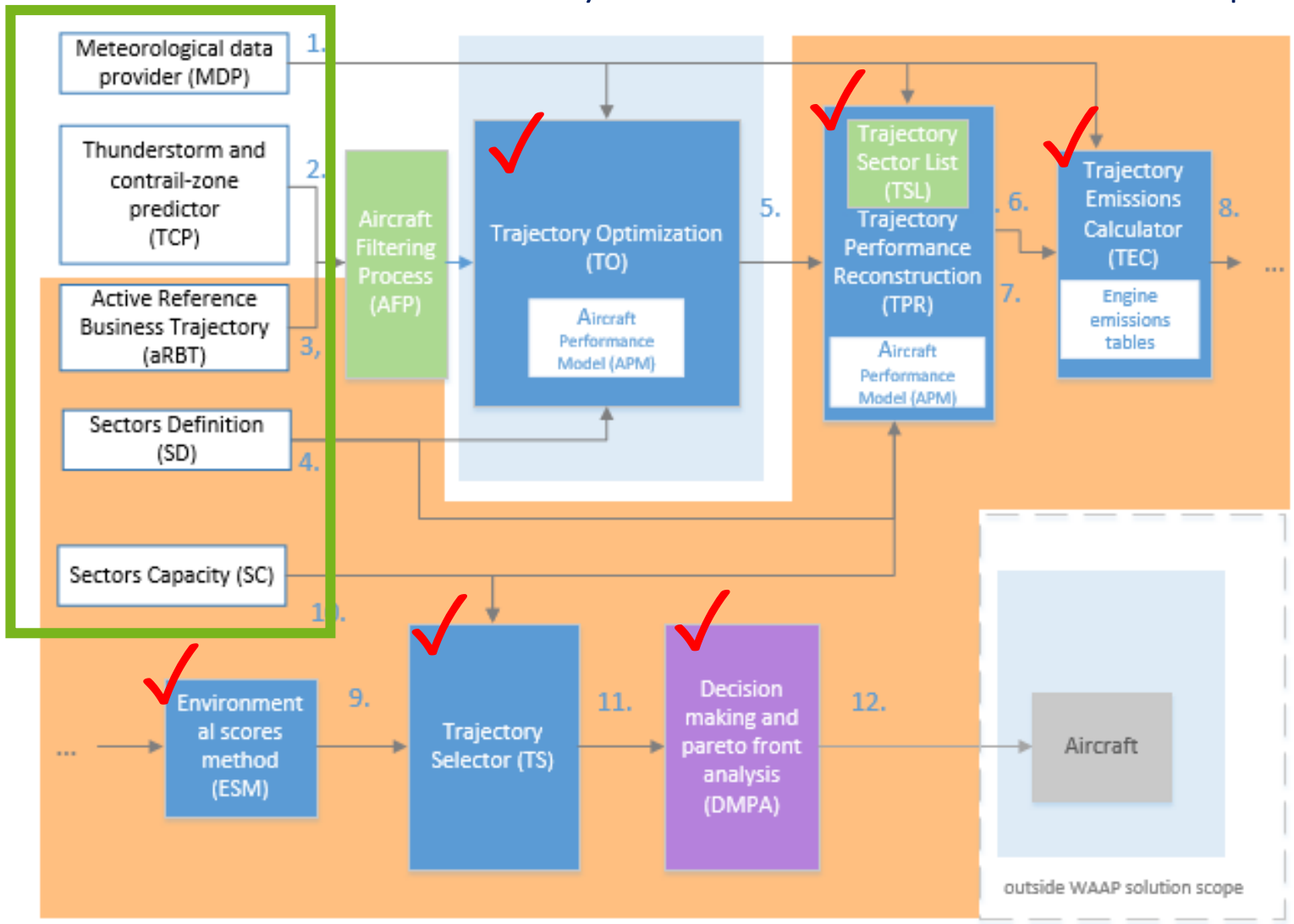
Scenario sketch

CREATE-SOL-2: Multi-aircraft environmentally-scored weather-resilient optimized 4D-trajectories



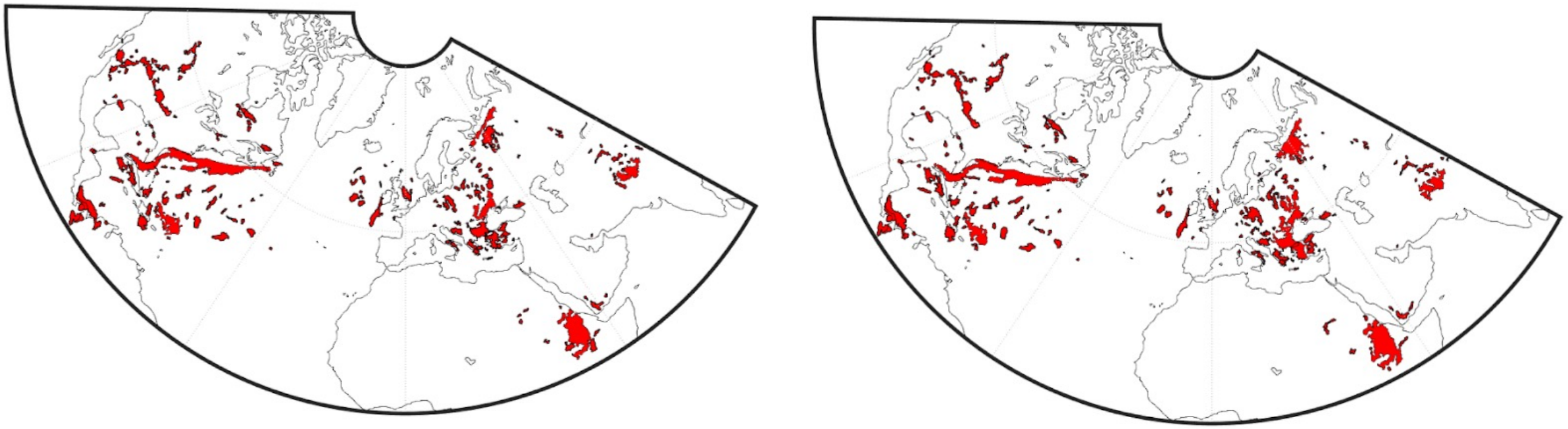
The framework

CREATE-SOL-2: Multi-aircraft environmentally-scored weather-resilient optimized 4D-trajectories



An example of application – en-route

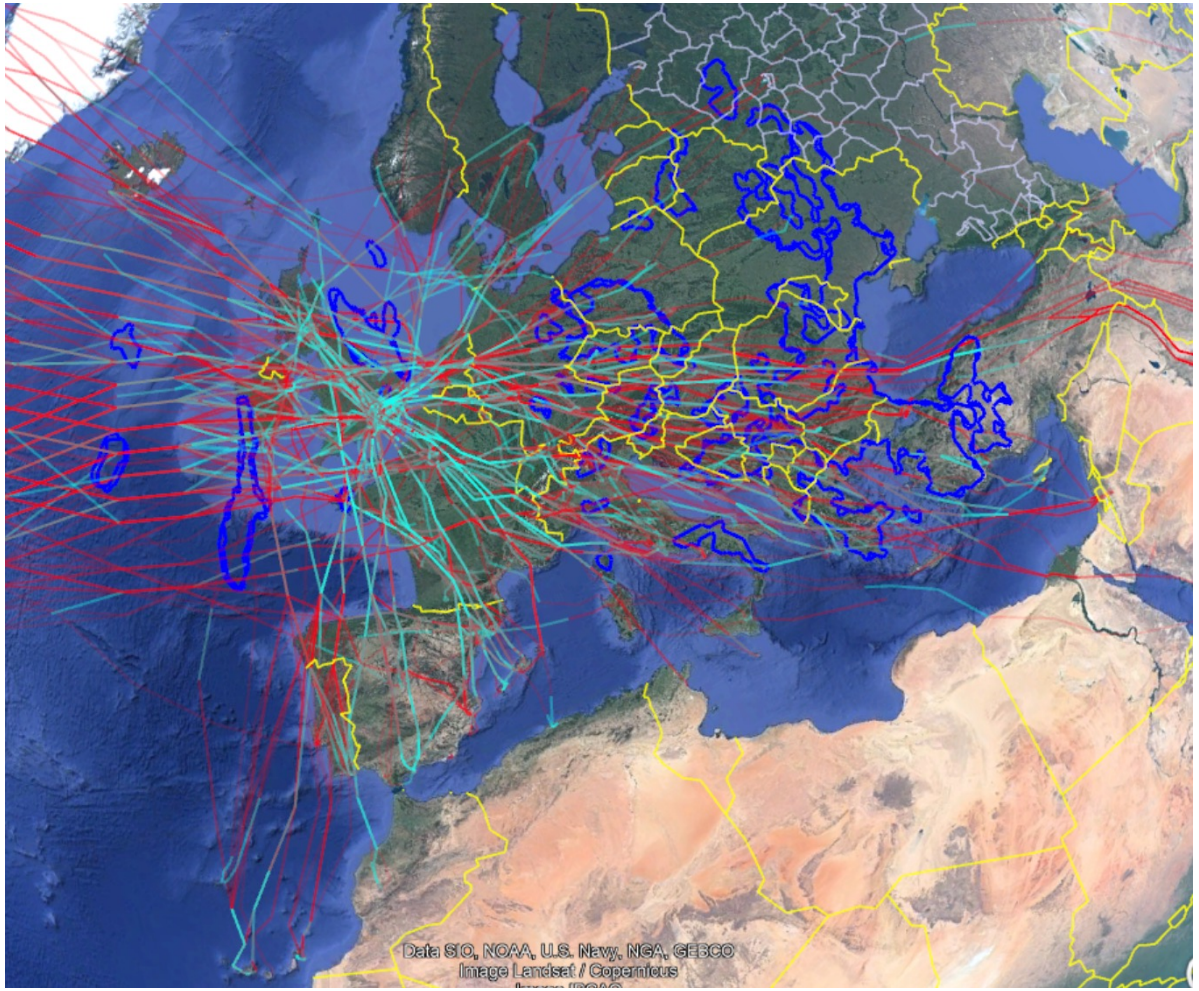
CREATE-SOL-2: Multi-aircraft environmentally-scored weather-resilient optimized 4D-trajectories



Weather related no-fly areas by using CAPE > 120 J/kg and precipitations > 0.3 mm/h (July 27, 2018).
Left: Z10:00; right Z10:30

An example of application – en-route

CREATE-SOL-2: Multi-aircraft environmentally-scored weather-resilient optimized 4D-trajectories



Case study 1: 1152, 1160, 1173, 1181, 1183 flights for 9 AM, 9.30 AM, 10 AM, 10.30 AM and 11 AM on July 27, 2018

Case study 2: 393, 319, 269, 235, 227 and 153 flights for 4 PM, 4.30 PM, 5 PM, 5.30 PM, 6 PM and 6.30 PM

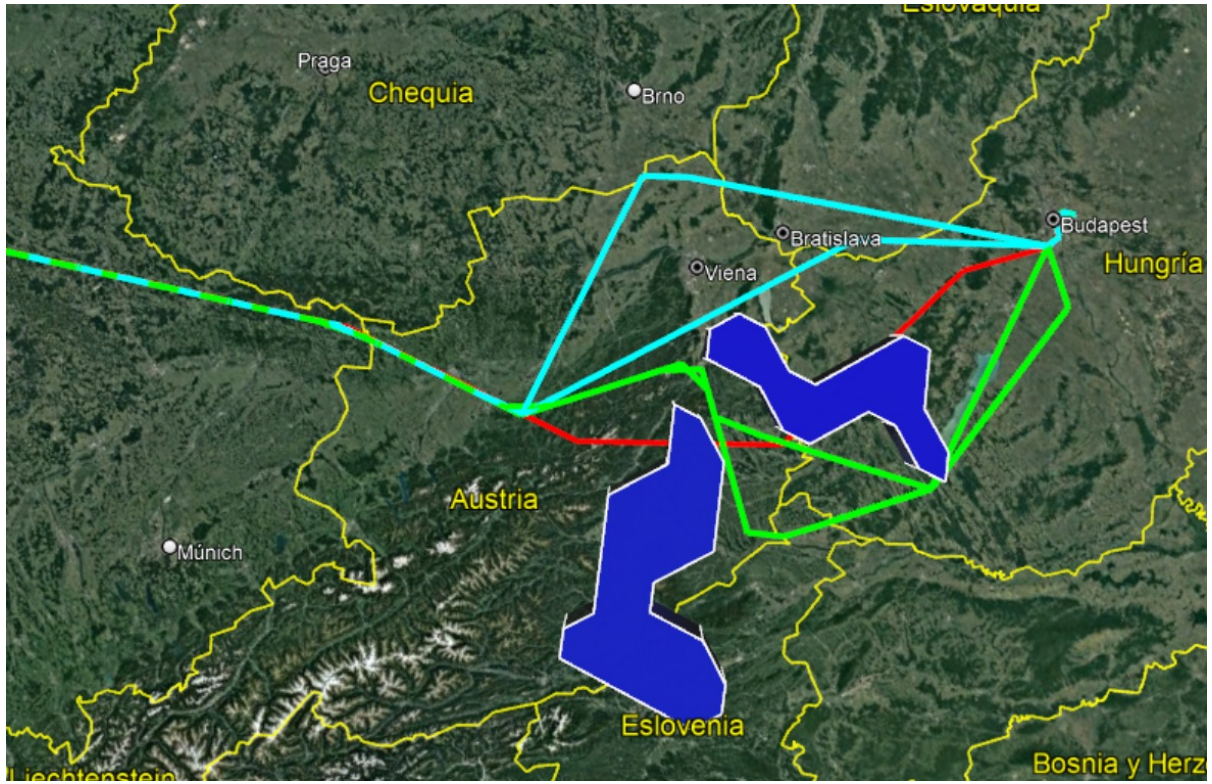
Up to 14 alternative trajectories were computed for each flight

The total time to run all the simulations for one time period took a minimum of 3.8 minutes (at 6.30 PM) and a maximum of 54 minutes (at 11 AM)
Laptop computer running Ubuntu 20.04 LTS, with 16GB of RAM memory and an Intel(R) Core(TM) i7-1185G7 @ 3.00GHz processor

An example of application – en-route

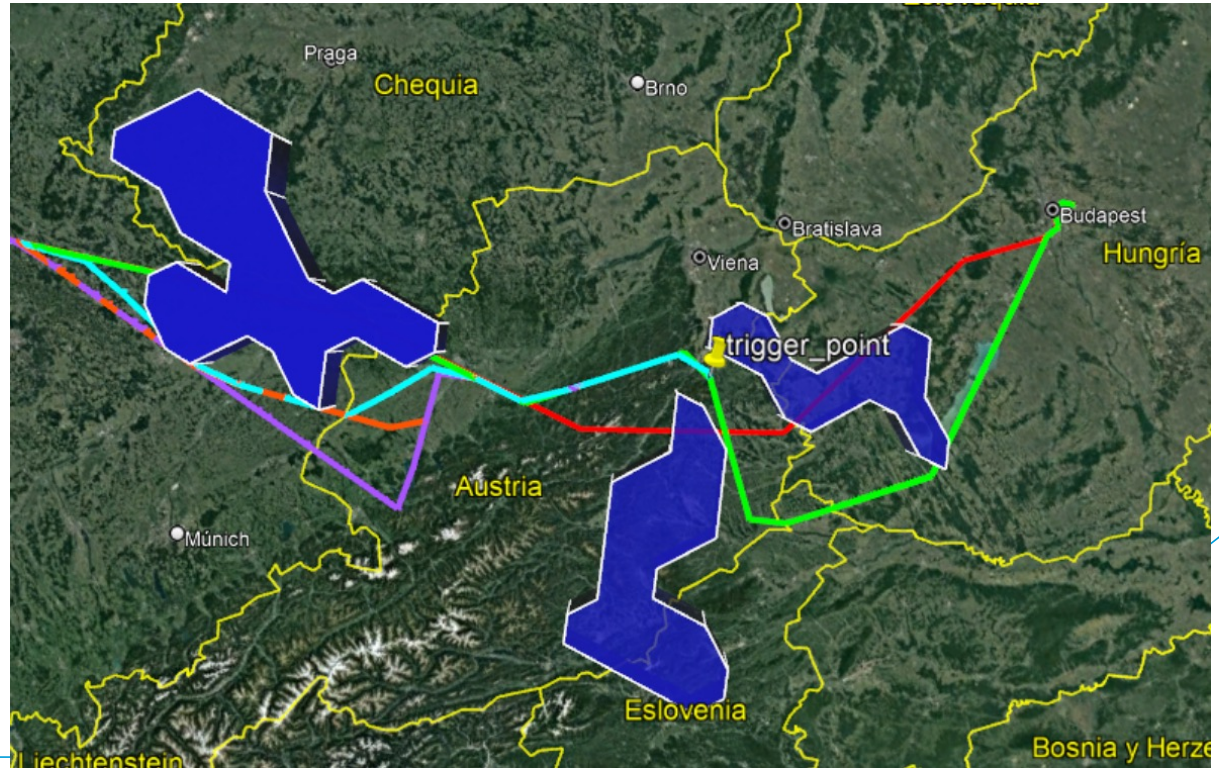
CREATE-SOL-2: Multi-aircraft environmentally-scored weather-resilient optimized 4D-trajectories

LOT33, a Boeing B787-800 flying from Budapest airport (LHBP) to JFK airport (KJFK) on July 27, 2018



Iteration from 10:00 to 10:30

Iteration from 10:30 to 11:00



Trajectory Selector (TS) and Decision Making Pareto Front Analysis (DMPA)

The TS is based on a MILP (mixed-integer linear programming) model with several constraints to ensure the demand is below capacity for all sectors and with the following objective function, considering the environmental score and the AUs extra costs due to the extra direct operating costs and delay:

$$J = \sum_{a \in \mathcal{A}} z_a [w_e E_k + w_c C_k + w_d D_k]$$

In the DMPA, several weights are assigned to the different elements present in the TS objective function

The environmental score is based on pollutant emission, weighted with respect the background concentrations

$$E_k = \frac{\sum_i (\sigma_{yi}\sigma_{zi} \times EMP_i \times CP_i)}{\sum_i CP_i}$$

EMP_i is the pollutant *P* emission
CP_i is the pollutant *P* environmental concentration
$\sigma_{yi}\sigma_{zi}$ = a normalization factor to take into account for cross-track and vertical dispersion

Indicators are computed for NOx and PM10

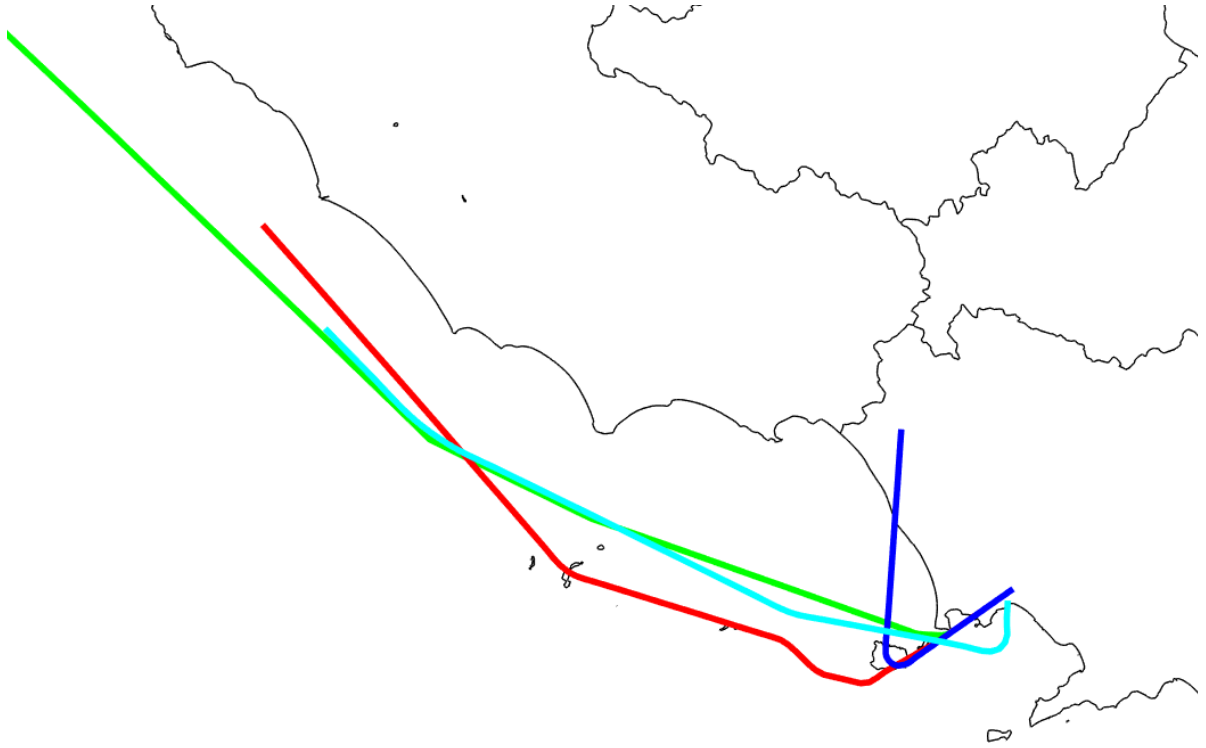
An example of application – TMA

CREATE-SOL-2: Multi-aircraft environmentally-scored weather-resilient optimized 4D-trajectories

Original reference trajectories for TMA phase

Naples-Capodichino Airport (No sectorization)

Dates: 02/27/2018



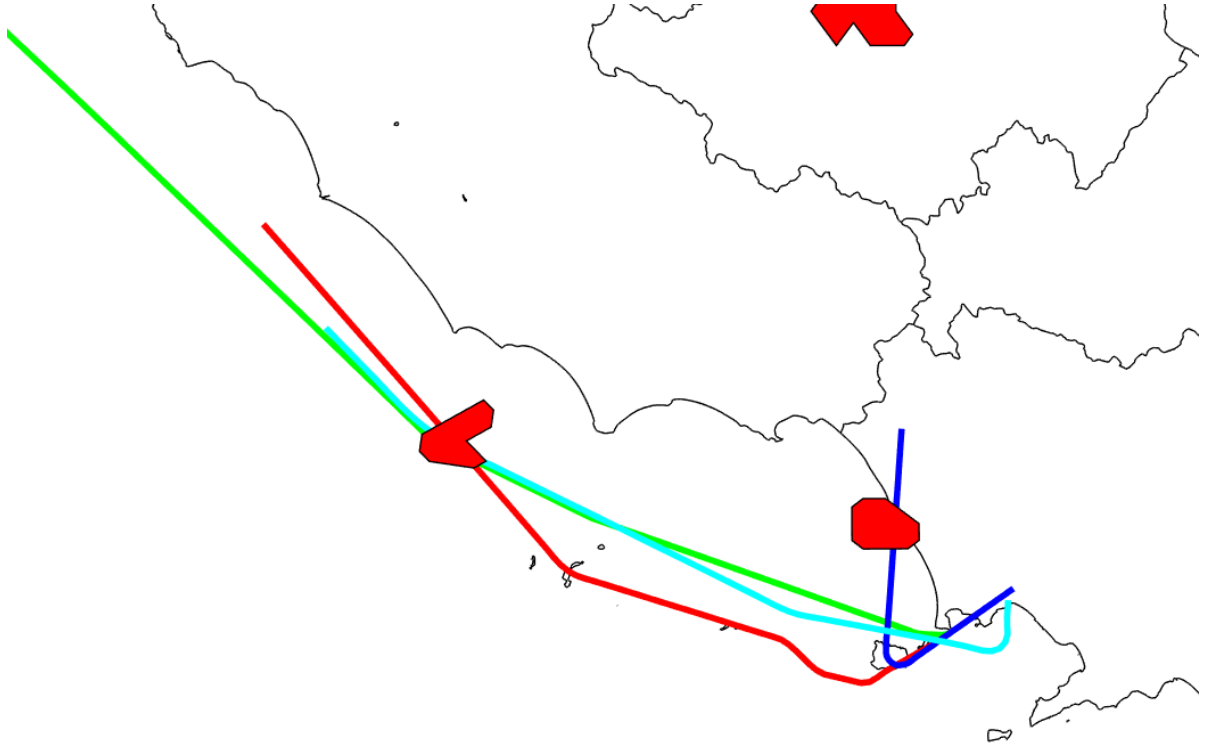
An example of application – TMA

CREATE-SOL-2: Multi-aircraft environmentally-scored weather-resilient optimized 4D-trajectories

Original reference trajectories for TMA phase + NFZ

Naples-Capodichino Airport (No sectorization)

Dates: 02/27/2018



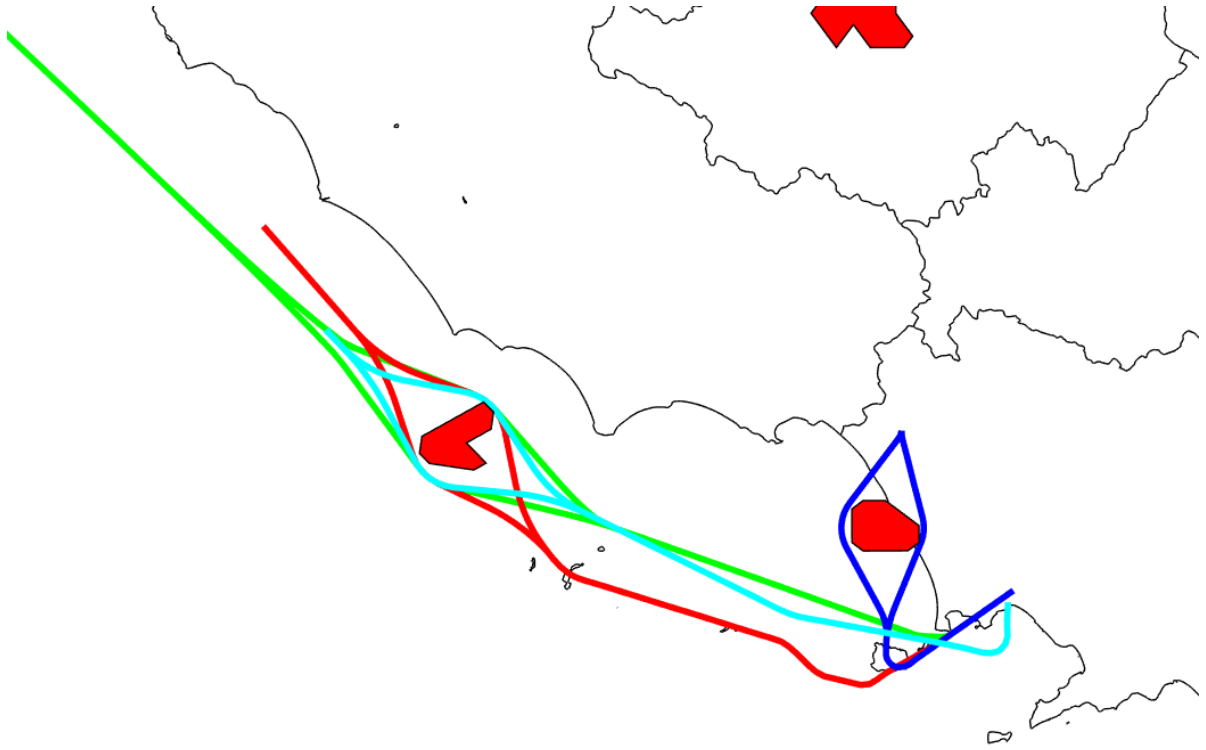
An example of application – TMA

CREATE-SOL-2: Multi-aircraft environmentally-scored weather-resilient optimized 4D-trajectories

Optimized trajectories (TO module) for TMA phase + NFZ

Naples-Capodichino Airport (No sectorization)

Dates: 02/27/2018



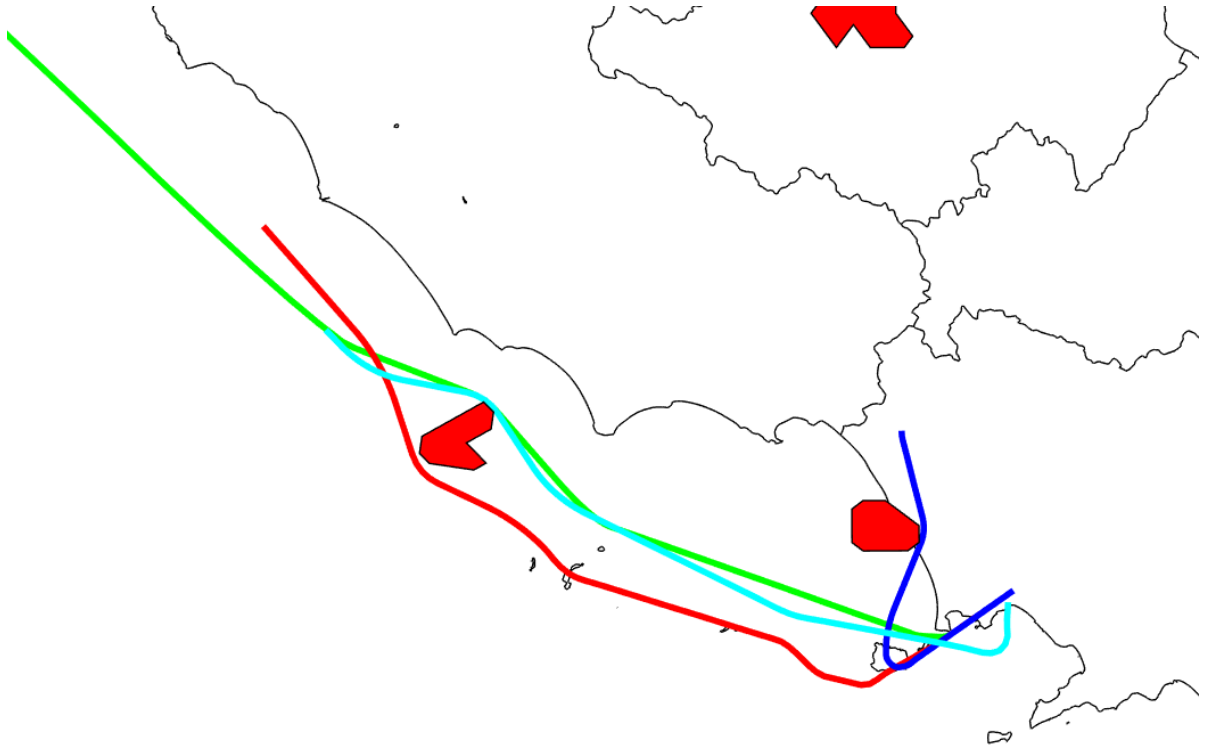
An example of application – TMA

CREATE-SOL-2: Multi-aircraft environmentally-scored weather-resilient optimized 4D-trajectories

Selected trajectories (TS module) for TMA phase + NFZ

Naples-Capodichino Airport (No sectorization)

Dates: 02/27/2018

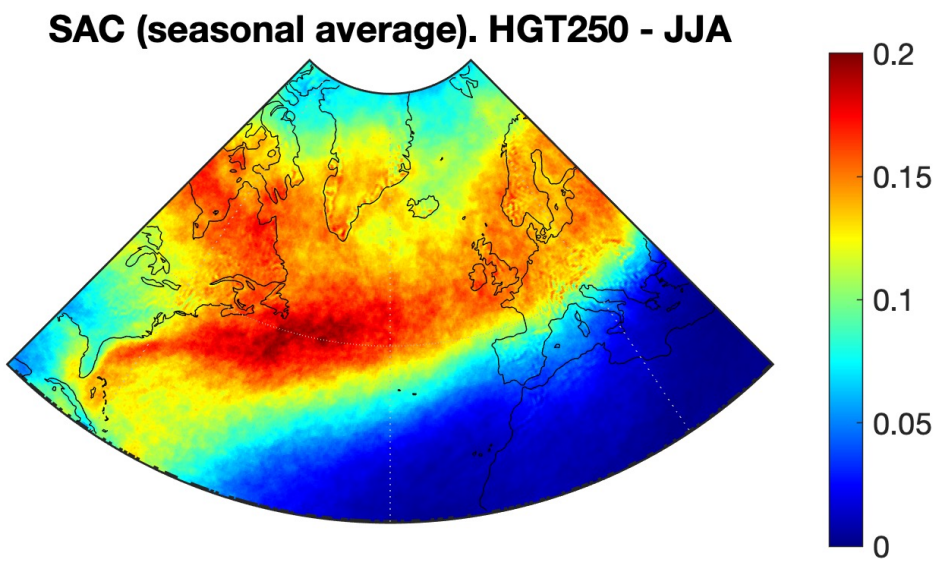


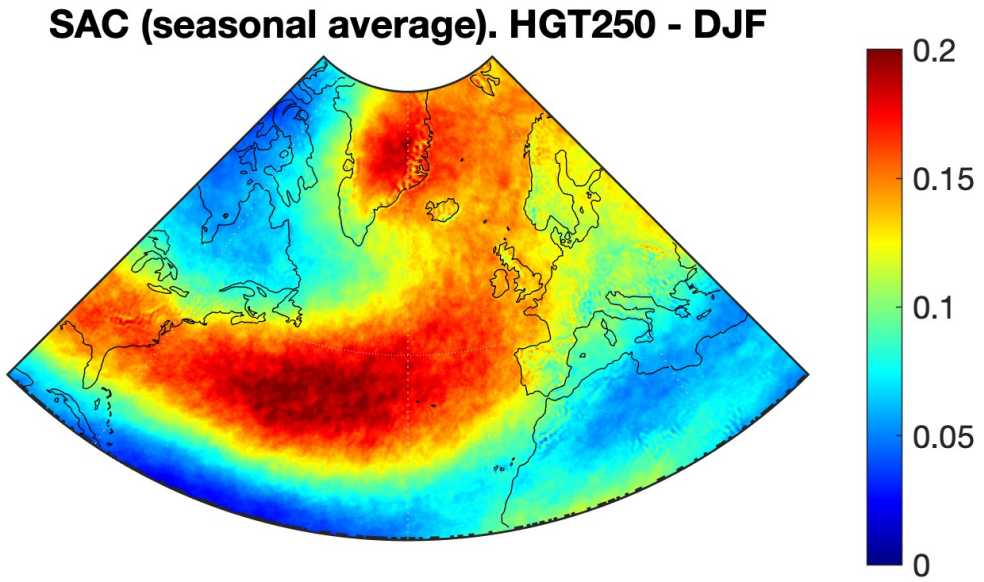
Remarks

- The framework allows to generate a set of alternative trajectories per flight in a multi-aircraft environment with the TO module, avoiding weather related no-fly areas and contrail-sensitive areas located across the original trajectory
- The algorithm is fast enough to be used (and re-used) also for real-time applications, given the background information on weather and air quality
- An environmental score has been introduced in the optimization goal function, as well as constraints taking into account the capacity of airspace sectors
- The final aim is to develop innovative procedures for the ATM system to reduce the climate and environmental impact of aviation, while increasing the resilience of air operations to weather phenomena.

The CREATE ConOps framework

CREATE-SOL-3: CO_2 and non-CO_2 balanced Environmental Scores Module (ESM)





Probability to encounter a constrail-sensitive area (CSA) for the winter season (DJF, right), and summer (JJA, left) seasons

Data are estimated from temperature and relative humidity fields from all years (1979-2020) of the ERA5 database at 250 hPa

The CREATE ConOps framework

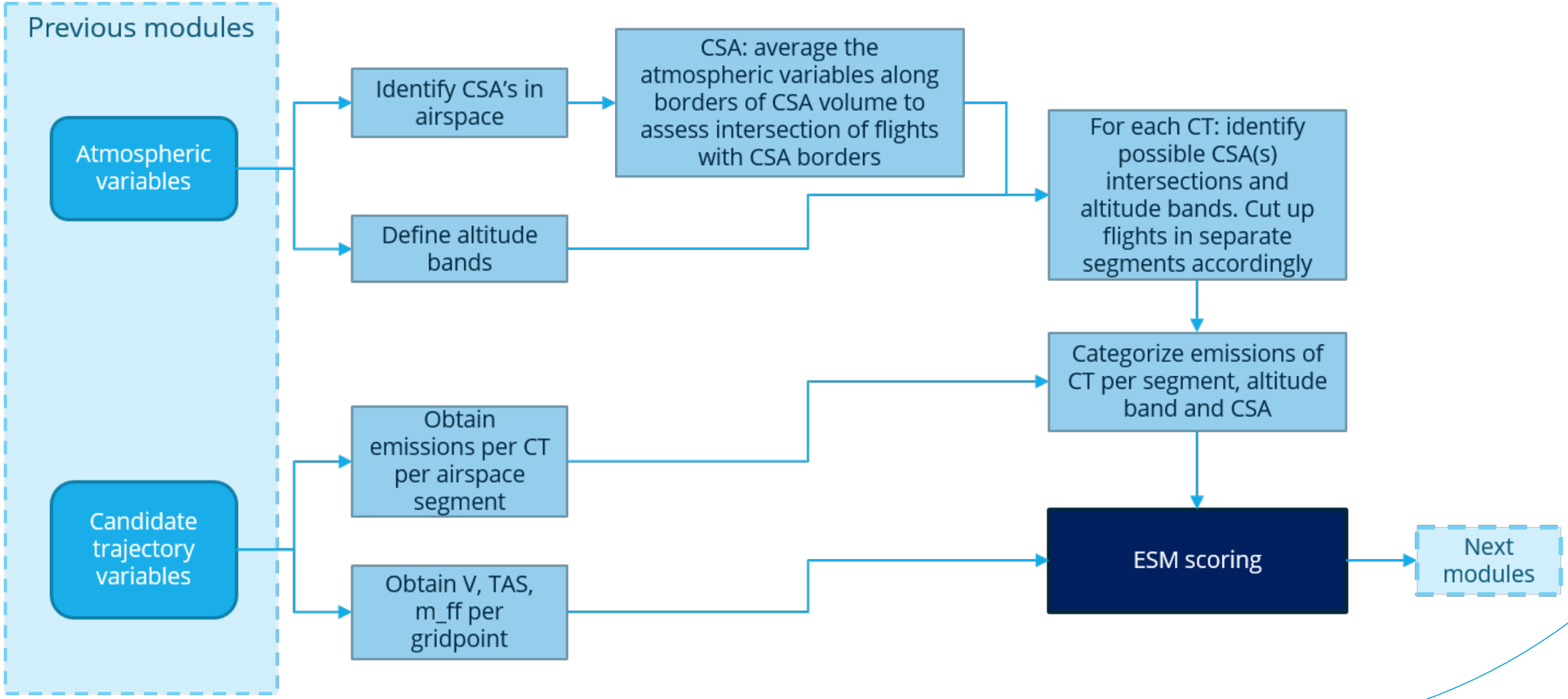
CREATE-SOL-3: CO_2 and non-CO_2 balanced Environmental Scores Module (ESM)

The Environmental Scoring Module (ESM) assigns scores to each candidate trajectory (CT). ESM considers non-CO_2; NO_x, H_2O and contrail formation

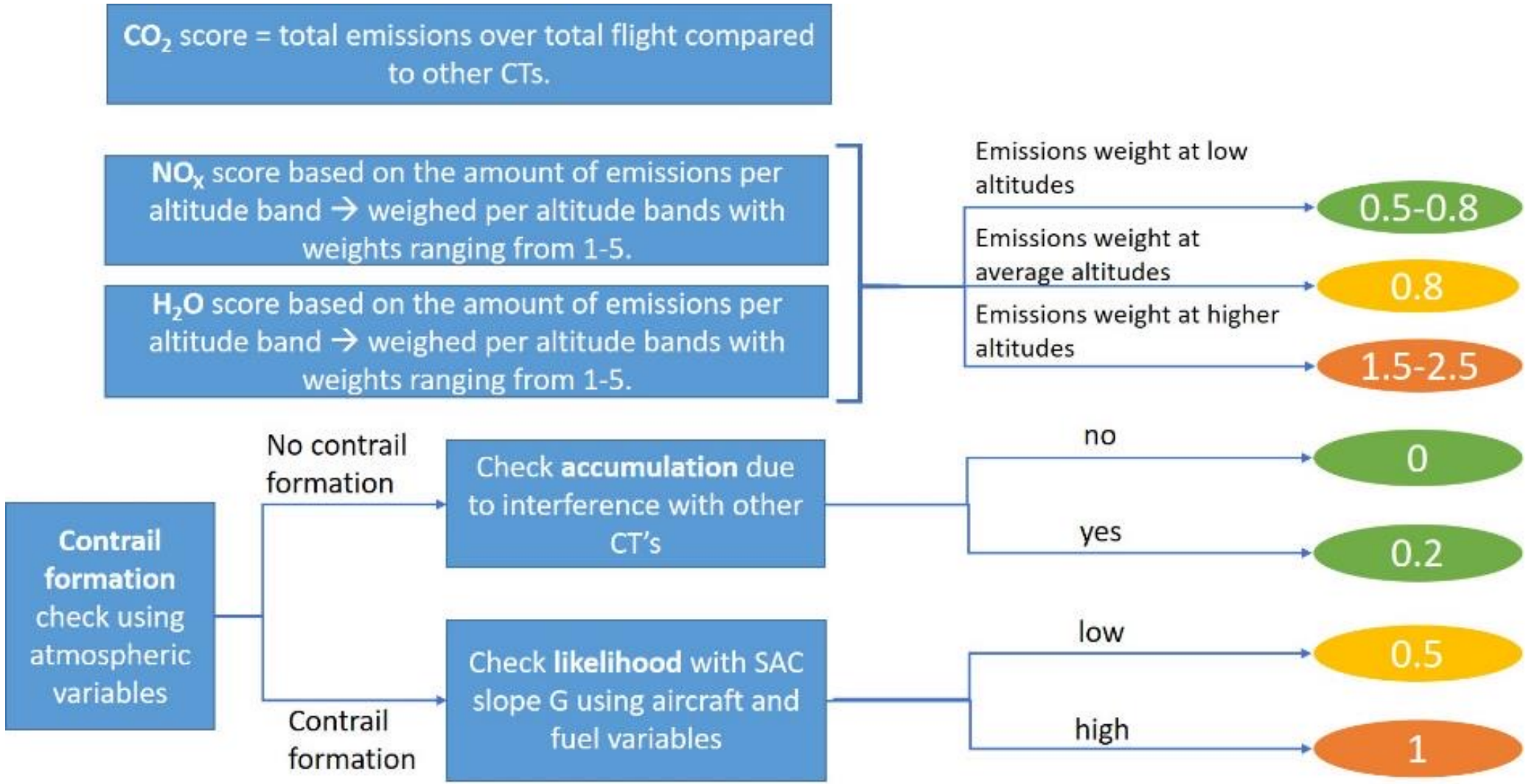
- CO_2 is linearly related to the total emitted amount per flight and therefore compared to other CTs
- NO_x and H_2O emissions impact are related to altitude.
- Contrail formation probability and impact are related to Climate Sensitive Areas (CSA)* and interference with other Candidate Trajectories.

*The current scope only considers Contrail Formation Region (CFR) to be relevant for the definition of CSAs

Solution schematic



ESM scoring elements



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