EXPERT PANEL FOR POLLUTING EMISSIONS REDUCTION
EXPAPER

Valutazione d'impatto atmosferico a varie scale spaziali del traffico aereo
Progetto H2020 CREATE

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sesar
JOINT UNDERTAKING

CREATE

innovative operations and Climate and weatheR modEls to improve ATm resiliencE and reduce impacts

SESAR Joint Undertaking - European Union’s Horizon 2020 research and innovation program - GA No 890898 .

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Horizon 2020 SESAR project **CREATE**

Climate and weatheR modEls to improve ATM resiliencE and reduce its impacts

Project Objective

Achieve innovative procedures in ATM to reduce climate and environmental impact, basing on the analysis of short and long-term aviation impact on the environment at:

- Urban/local scale (air quality impact over the airport surroundings);
- global scale (overall aviation emissions impact on air quality and climate).

Method & Tools

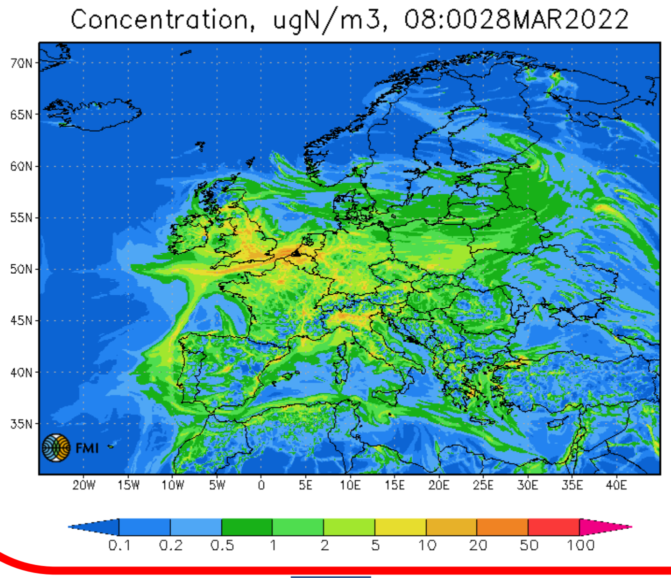
A cascade of interconnected air quality models:

- chemical transport models FMI/SILAM (global and continental scale) and FARM (urban scale), nested through boundary conditions
- Lagrangian particle model SPRAY (local scale);
- obstacle resolving Lagrangian particle model PMSS (microscale, airport vicinity).

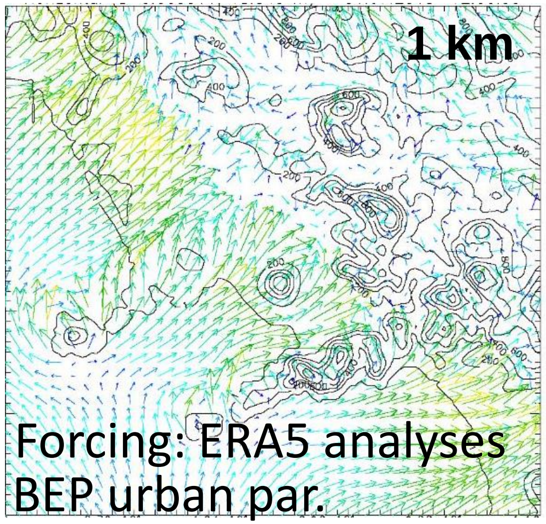
Case study

- Naples Capodichino: mid-size European airport located in urban environment

Regional scale air quality (SILAM)

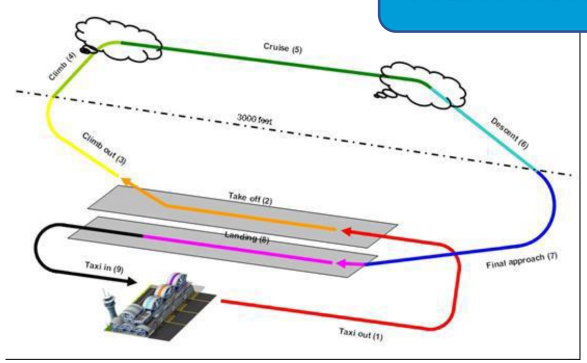


Urban scale meteorology (WRF)



Italian emission inventory

+ AEM Kernel

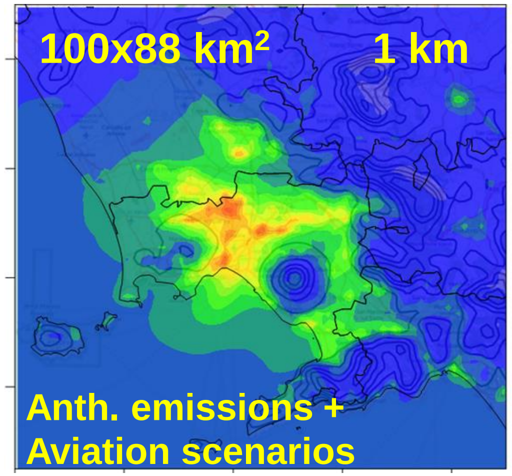


Aircraft+airport emissions

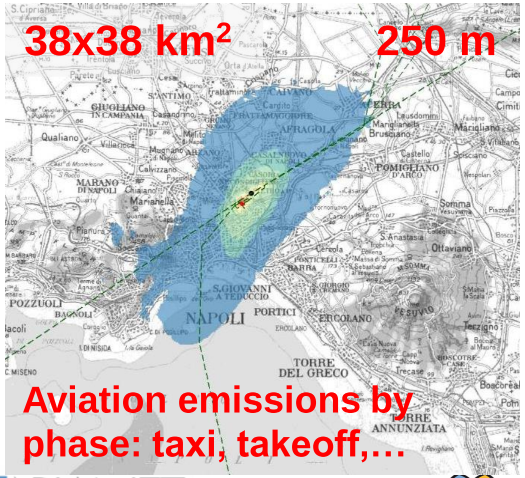
air quality

air quality

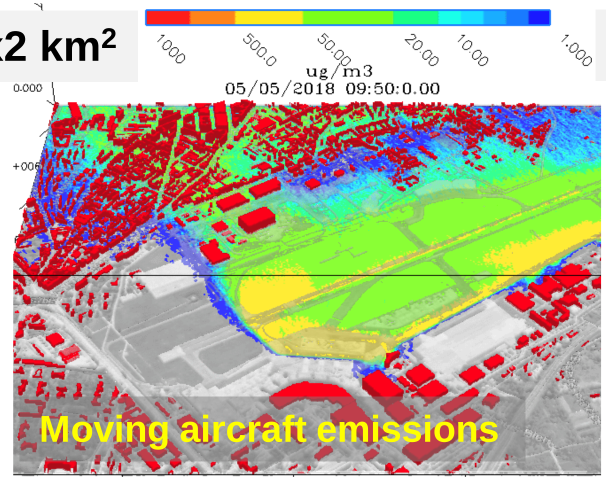
Urban scale CTM (FARM)



Local scale LPM (SPRAY)



Obstacle resolving LPM (PMSS)



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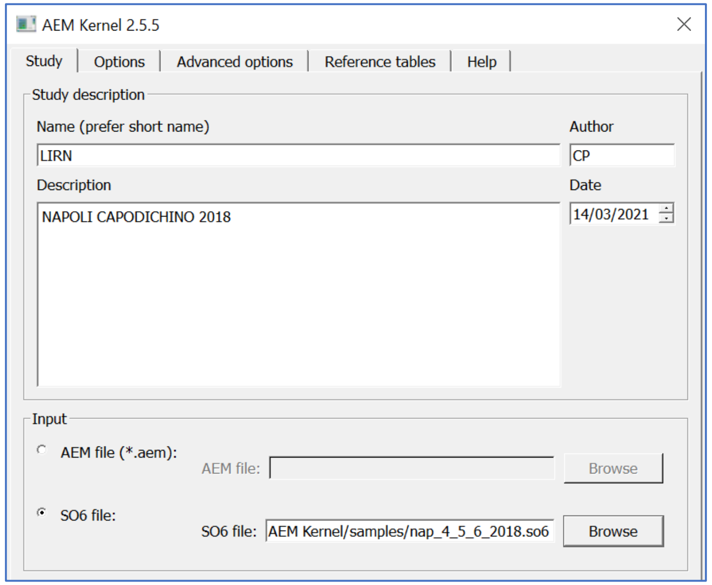
Airport bottom-up inventory (including LTO cycles and flight trajectories inside the 180x176 km^2 computational domain) vs total emissions over Campania Region (5.6 M inhabitants)

	CO/10	NMVOC	NH3	NOx	PM2.5	PM10	SO2
Capodichino airport (t/year)	24	27	0	1407	13	13	71
% Campania Region	0.13%	0.05%	0.00%	2.48%	0.08%	0.06%	3.08%

Bottom-up annual emission estimate for the Napoli Capodichino airport

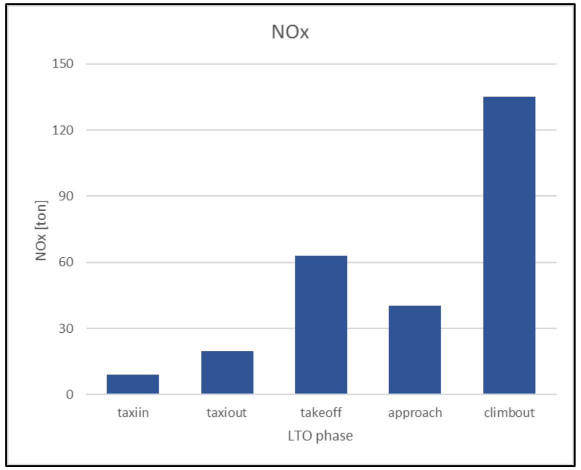
- TOOL: EUROCONTROL AEM Kernel emission calculation. It provides the mass of fuel burned by the main engines [g_{Fuel}/s] and the corresponding masses of certain gaseous and particulate emissions [g_{Poll}/g_{Fuel}] by a specified type of aircraft with a specified type of engine(s) flying a specified 4D trajectory for each LTO phase.
- Input data: flight register from/to Napoli Capodichino (LIRN) in 2018 (For each of the 61,896 flights is provided the aircraft type, number and model of engines, specific time in mode)
- Example from the processed AEM Kernel **input .so6** file for LIRN case study :

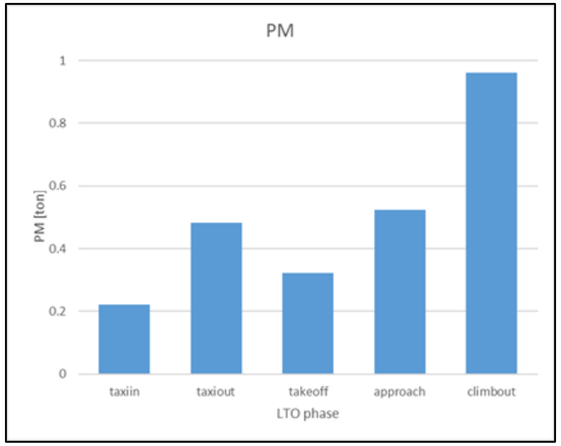
```
A32001013425810810 7 CDG  LIRN  A320  081009  081409  4183  1499  7  342581  180101
180101  12.342  45.507  12.344  45.505  342581  1  2500  0
A31901014CA9B407087  TRN  LIRN  A319  070822  071222  4183  1499  7  4CA9B4  180101
180101  12.342  45.507  12.344  45.505  4CA9B4  1  2500  0
A3190101405F0B07117  MXP  LIRN  A319  071150  071550  4183  1499  7  405F0B  180101
180101  12.342  45.507  12.344  45.505  405F0B  1  2500  0
A32001014CA75907157  LIN  LIRN  A320  071542  071942  4183  1499  7  4CA759  180101
180101  12.342  45.507  12.344  45.505  4CA759  1  2500  0
A3190101405F0F08477  STN  LIRN  A319  084727  085127  4183  1499  7  405F0F  180101
180101  12.342  45.507  12.344  45.505  405F0F  1  2500  0
A3200101201080946 7  CMN  LIRN  A320  094622  095022  4183  1499  7  20108  180101  180101
12.342  45.507  12.344  45.505  20108  1  2500  0
E17001014CAA7607387  PMO  LIRN  E170  073819  074219  4183  1499  7  4CAA76  180101
180101  12.342  45.507  12.344  45.505  4CAA76  1  2500  0
A31901014O612F09367  LGW  LIRN  A319  093626  094026  4183  1499  7  40612F  180101
180101  12.342  45.507  12.344  45.505  40612F  1  2500  0
A3190101400EFC08157  VCE  LIRN  A319  081505  081905  4183  1499  7  400EFC  180101
180101  12.342  45.507  12.344  45.505  400EFC  1  2500  0
```

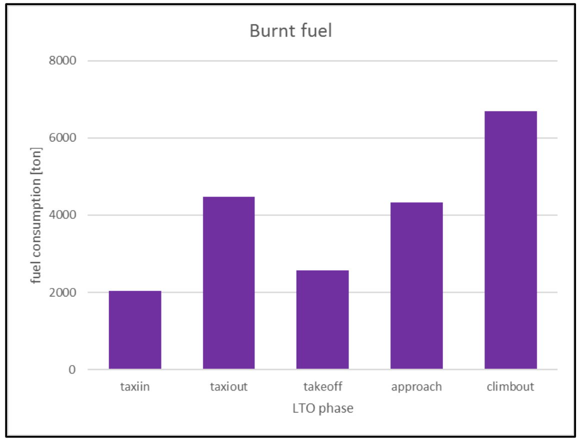


Bottom-up annual emission estimate for the Napoli Capodichino airport

- AEM Kernel provided emission results per each segment, or groups output records per flight or per attitude. These charts show the aggregated emission results by phase:







- According to different models the emission are represented in space and time with different levels of aggregation.

FARM	Gridded emission inventories cells
Spray	Linear / area emission sources
Micro-Spray	Single aircraft dinamic emissions

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SILAM (System for Integrated modeLling of Atmospheric composition)

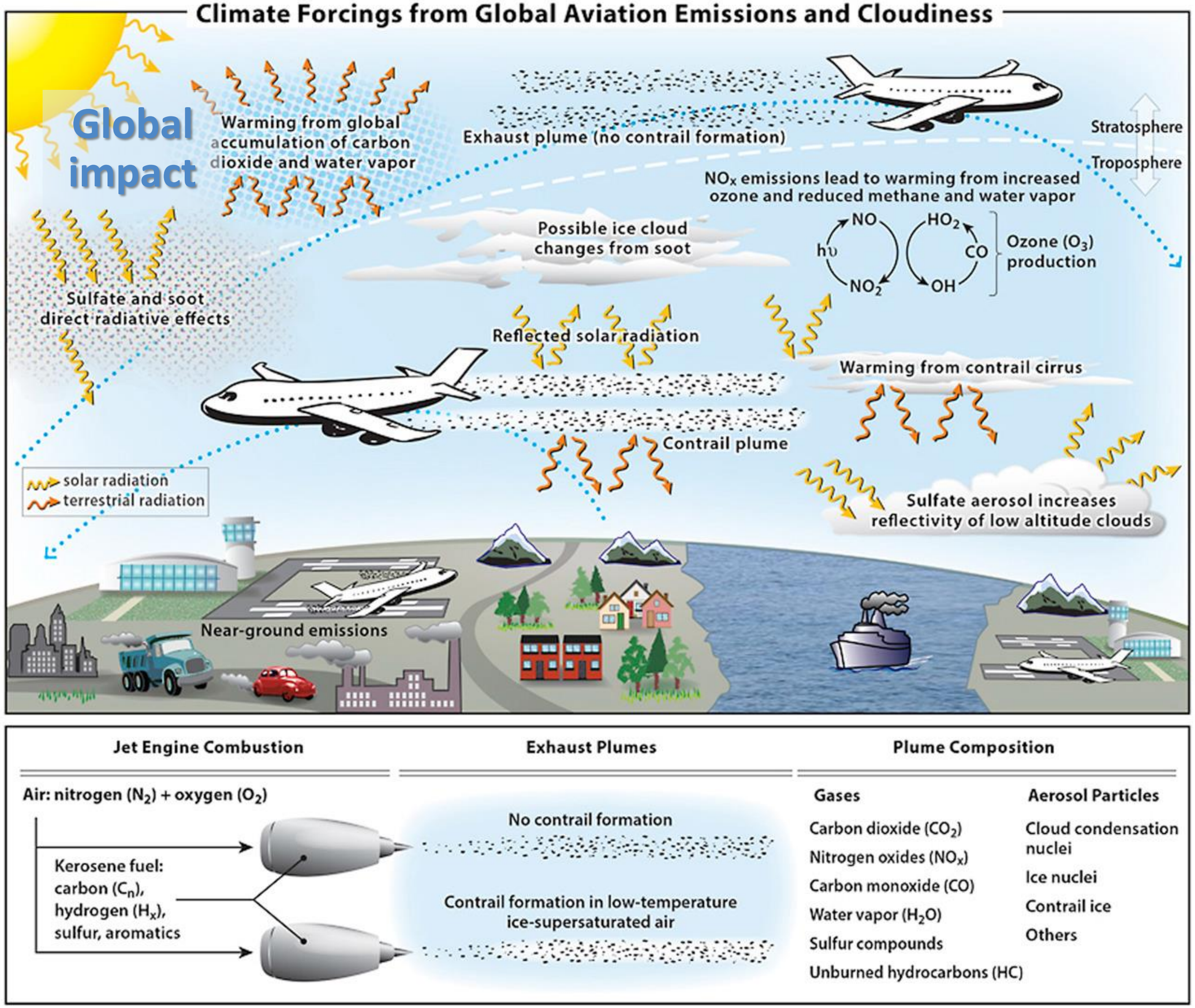


Figure from D.S. Lee *et al.*, Atm. Env. (2021).

SILAM

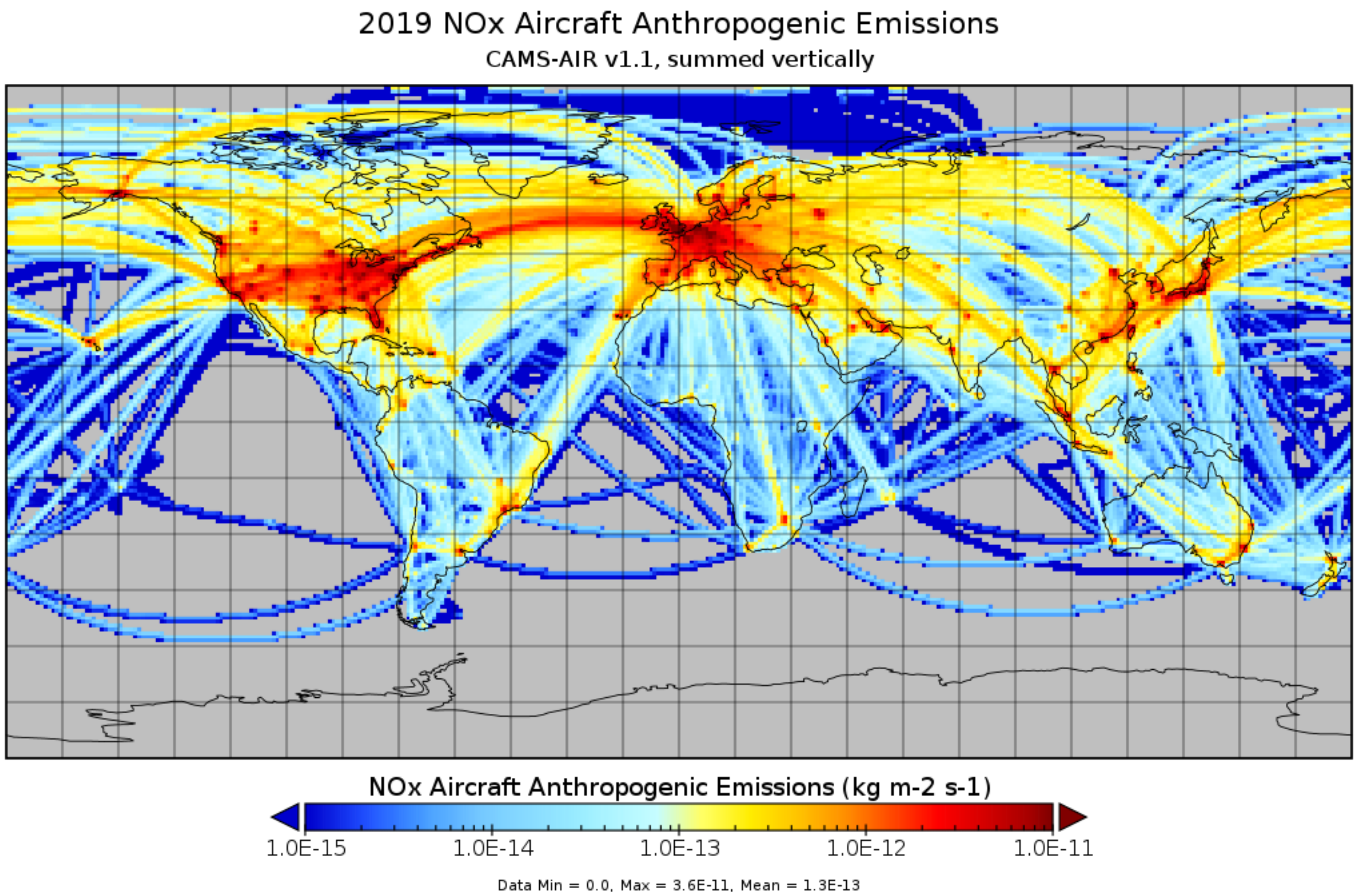
v.5.7 CTM using CBM05 chemistry including stratosphere:

- Various emissions from different inventories:
  - Antropogenic emissions (e.g. CAMS-GLOB-2.1/4.2)
  - Lightnings (GEIA)
  - Aviation (EDGAR4.3.2 / CAMS-AIR-1.1)
  - Biogenic (MEGAN-MACC, CAMS-BIO-3.1)
  - N2O, CFCs, CH3Cl and CH3Br *etc.*
- Secondary Organic Aerosols:
  - Based on volatility bin approach (e.g. Woody *et al.* ACP2015).
- Sea-salt emissions including its bromine factor:
  - Based on combined Monahan-Martensson method.
- Wind-blown dust source.
- DMS from seas.

Performed global simulations with and without aviation for years 2000–2019.
Additionally European region for 2010, analysing the effect of LTO emissions (not shown)

Global aviation emissions

See e.g.: D.S. Lee, *et al* (2021), The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018, Atmospheric Environment, Volume 244, 117834, and references therein.



- 2.5% of global CO_2 emissions
- 1.9% of global GHG emissions
- NOx: 2 Tg/year (lightning 5 Tg/year)
- Water contrails (net warming)
- Aerosols (cooling)

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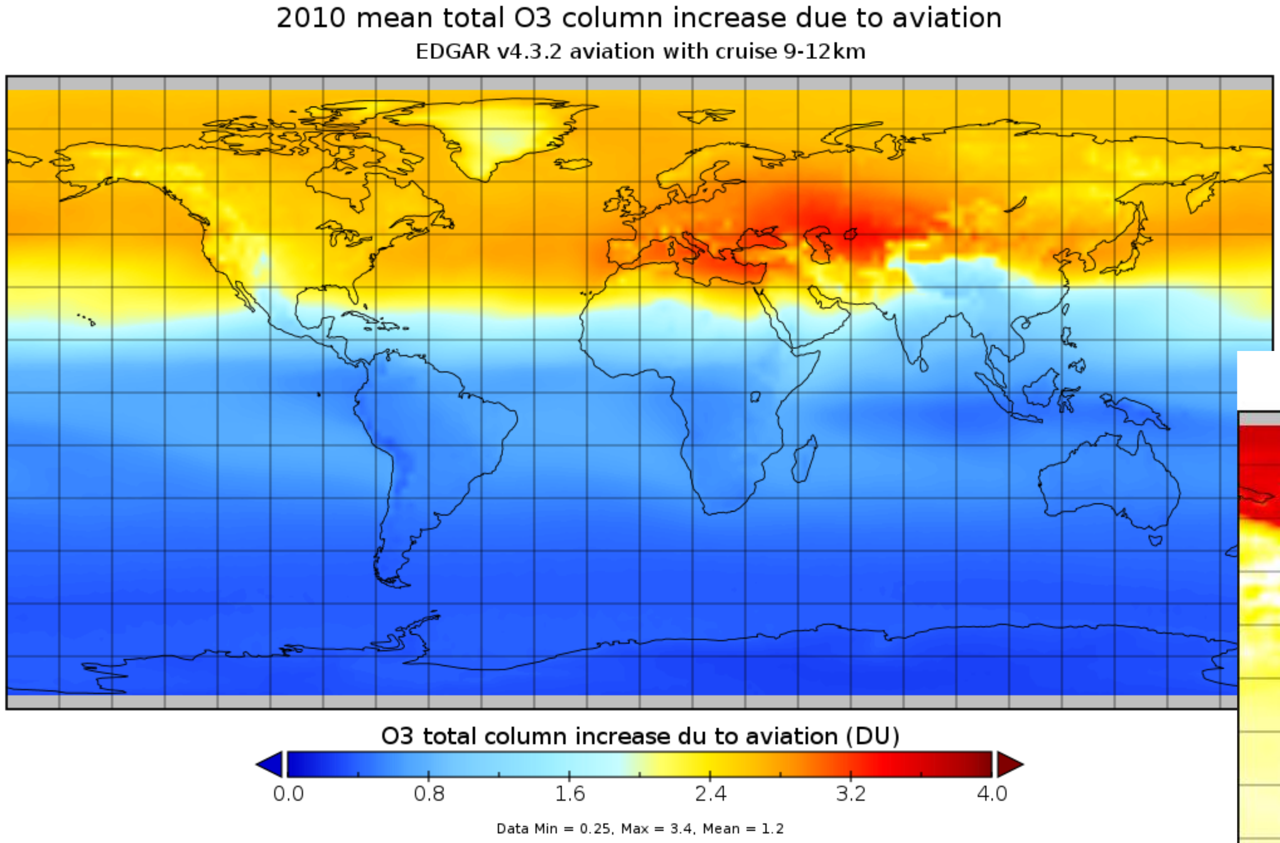
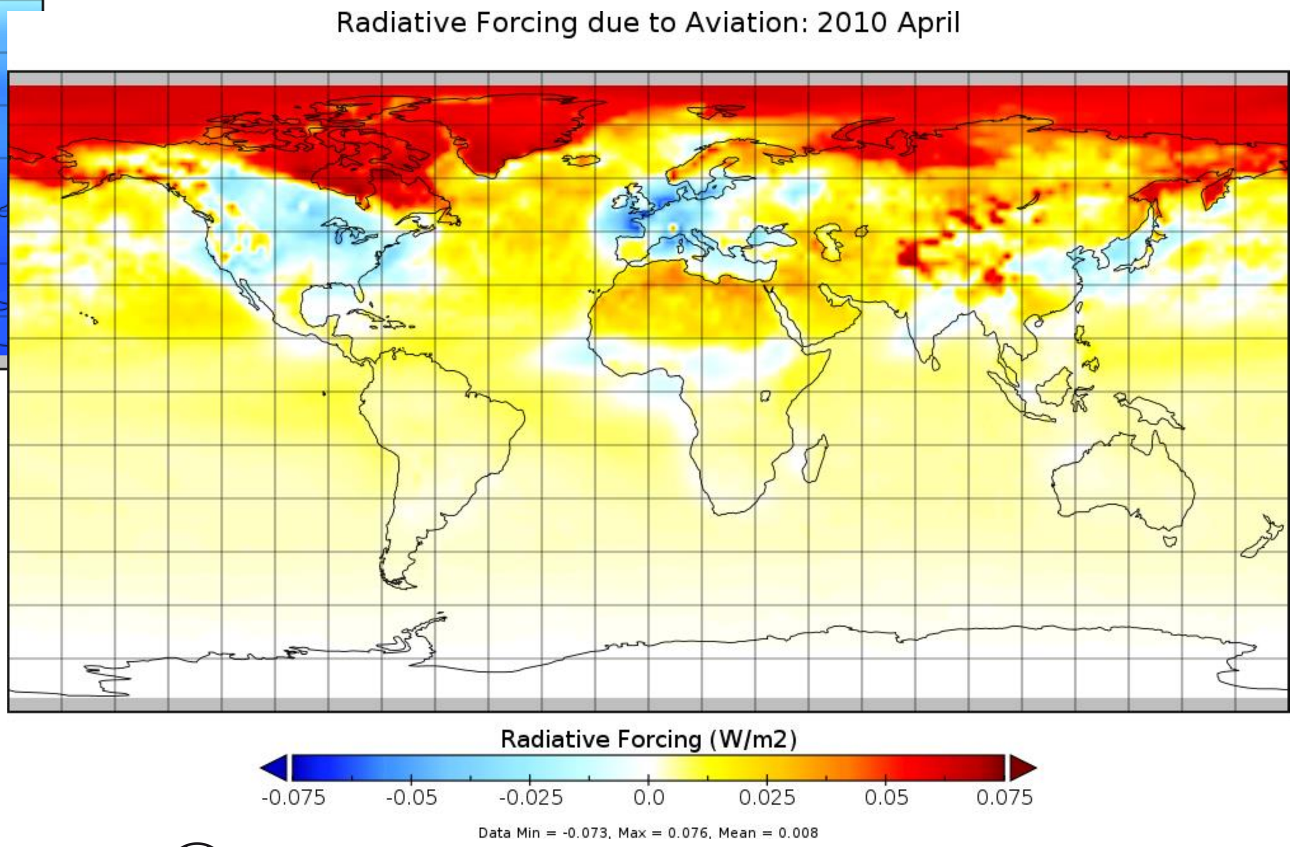
2010 annual total ozone column change and radiative forcing due to aviation





WP2 - Relation between environment and ATM

Deliverable D2.1

Aviation impact on local environment and long term & global phenomena

Concluding remarks

Global aviation emissions:

- aviation emissions increase ozone globally about 1 DU in one year (with max monthly mean increase 4-5 DU above Europe in May)
- radiative forcing: ozone has warming effect (RF +13 mW); direct aerosol effect is cooling (RF -4 mW)
- Effects seem smaller than warming due to contrail formation and CO_2 emissions

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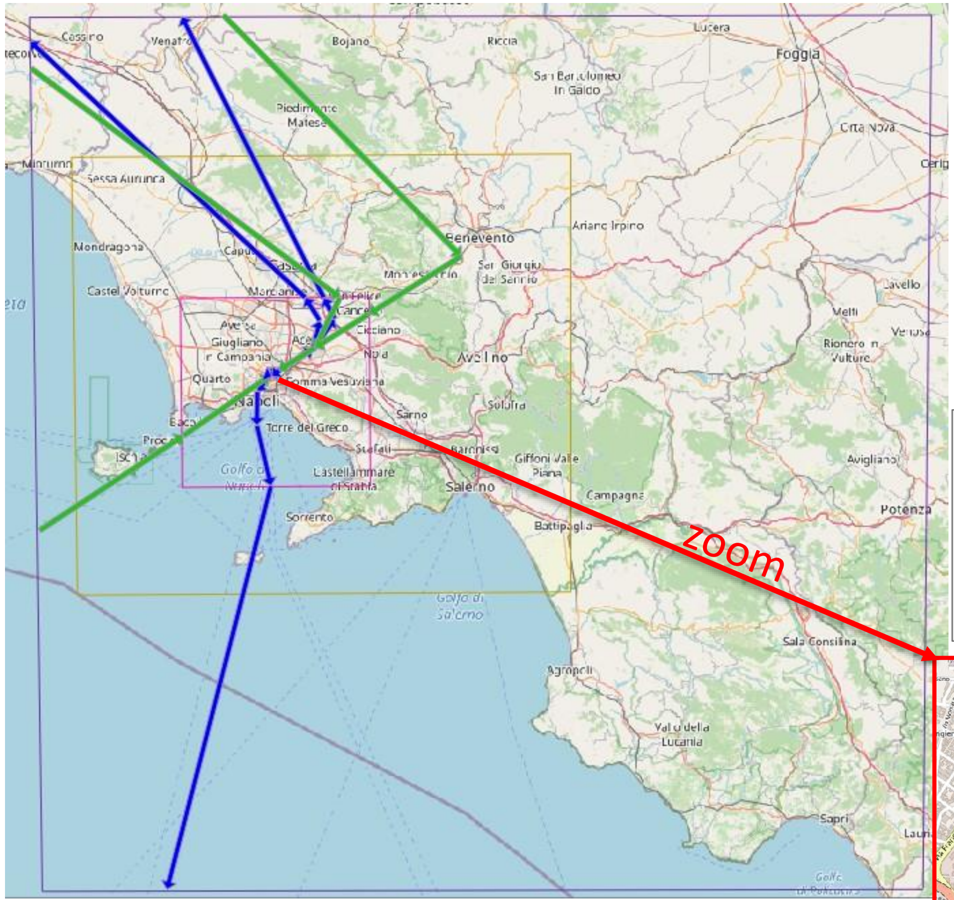
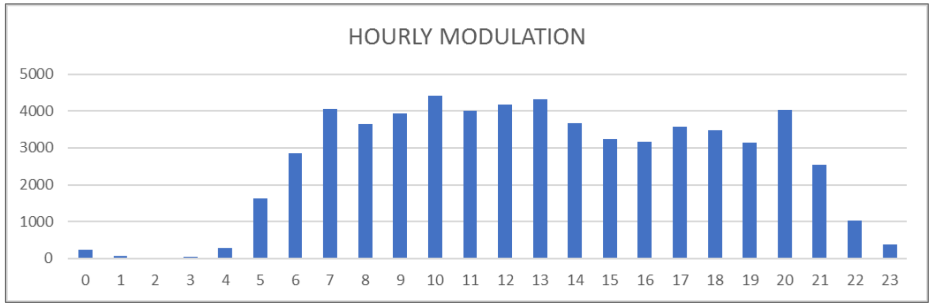
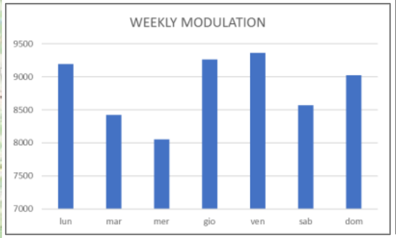
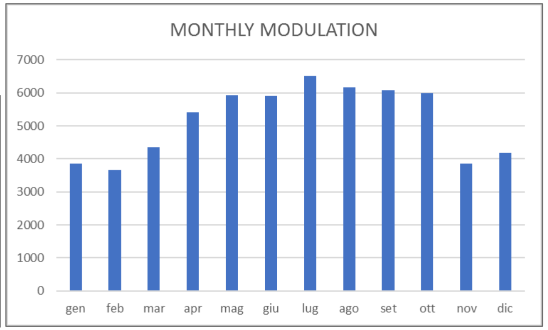
Urban and Local scale

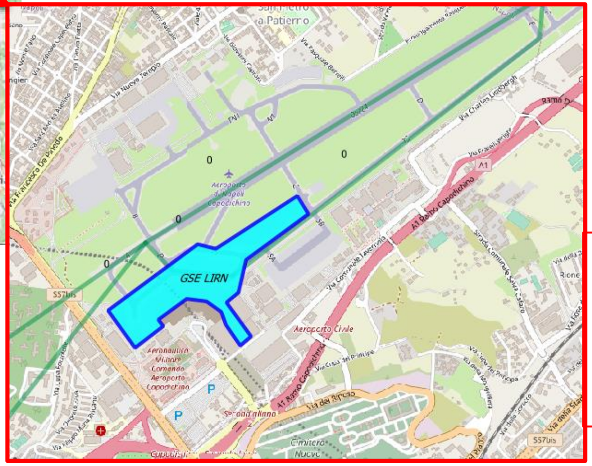
Emission features at local scale: linear/area sources and time disaggregation











GSE : Ground support equipment. vehicles/machines for aircraft assistance activities

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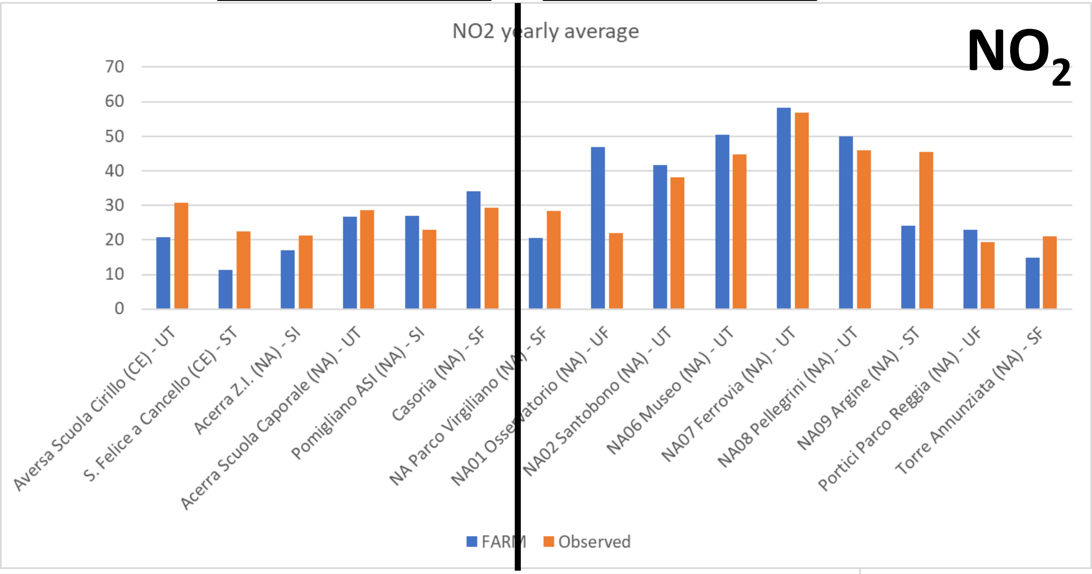
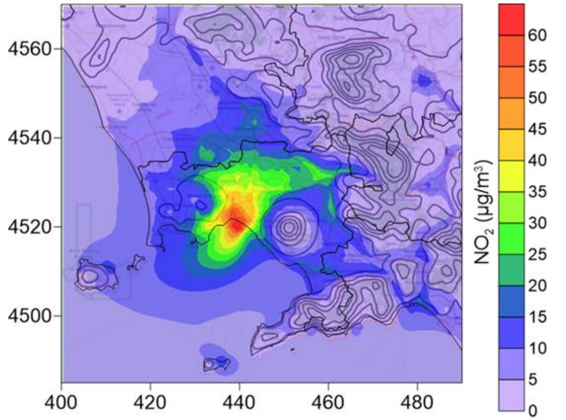
CTM results comparison with local observations

Inland area | Naples city

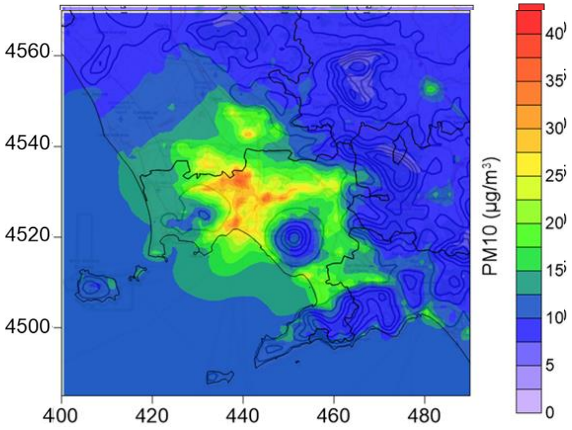
2018 - yearly average concentrations

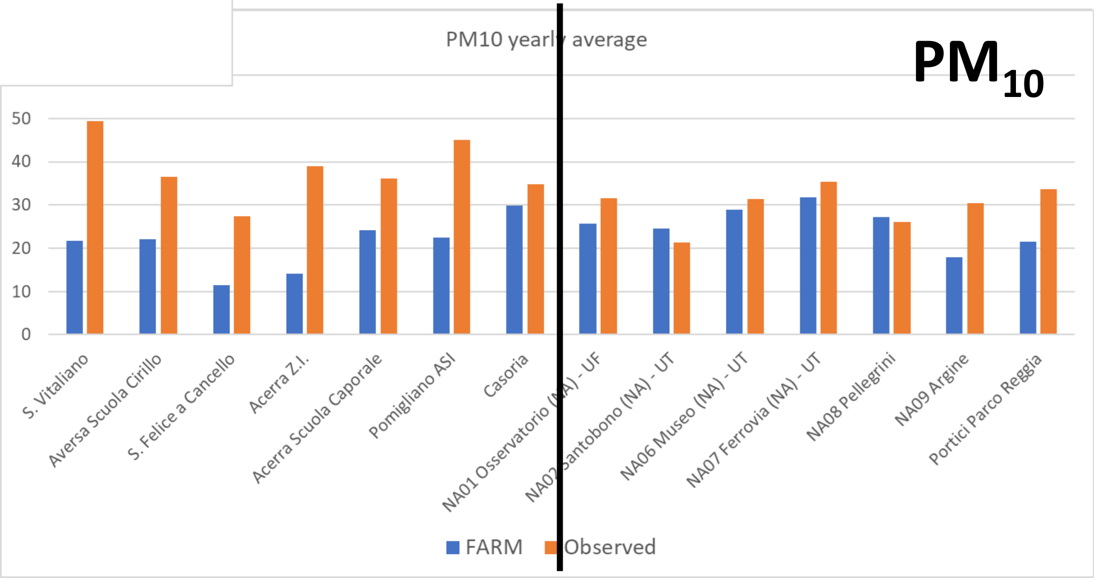




Predicted

Observed





Urban scale **CTM (FARM)**

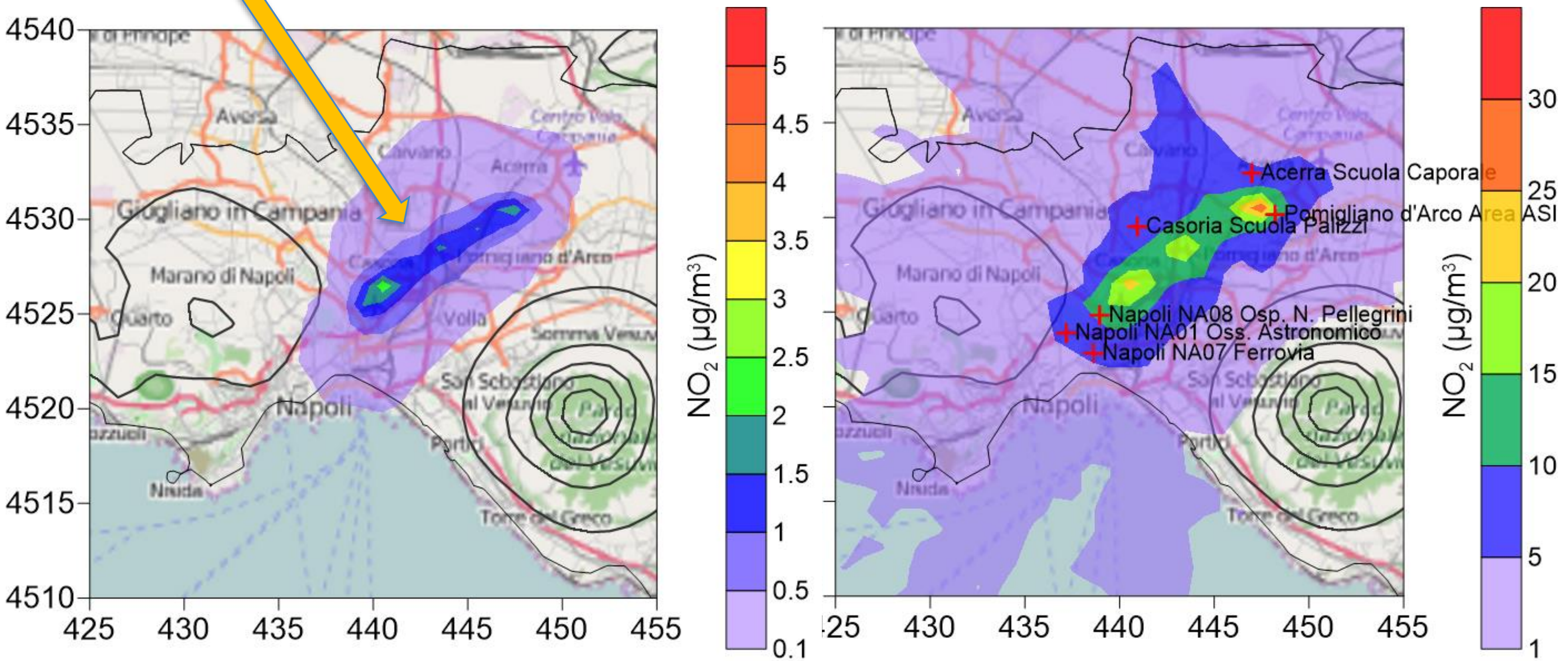
Airport and air traffic contribution

Take-off/landing plume
toward Acerra-Pomigliano

NO_2

Year 2018

mean **hourly maximum**



values > 1 µg/m³ nearby the airport and under the landing/takeoff trajectories

Hourly max. reaching 20-30 µg/m³

Airport and air traffic contribution

O_3

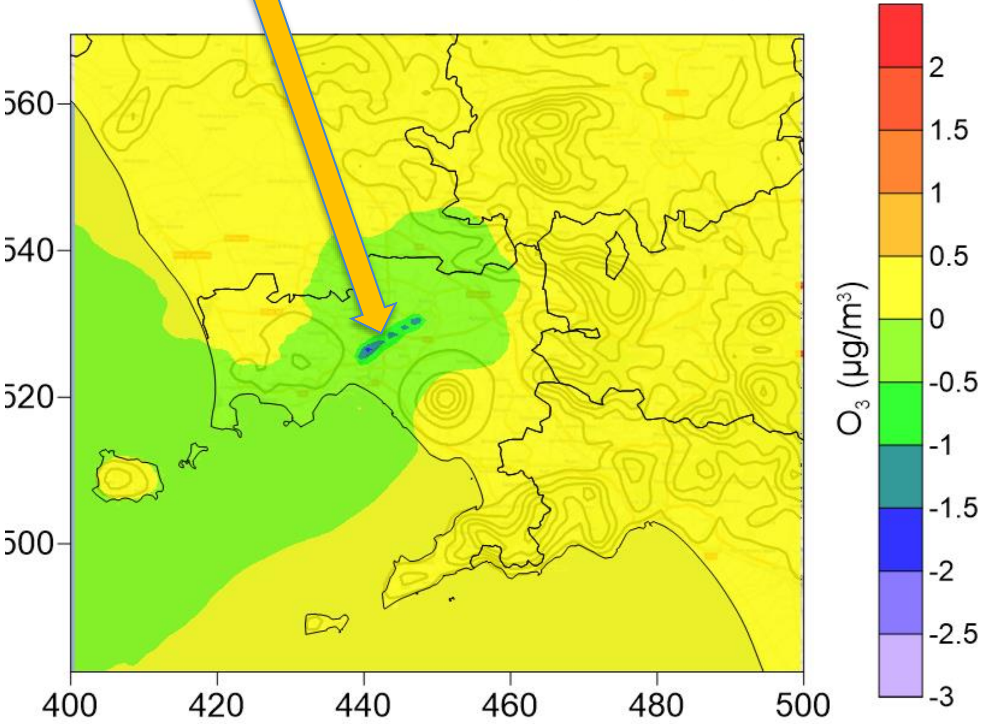
Year 2018

Negative values, prevailing ozone titration

Ozone production

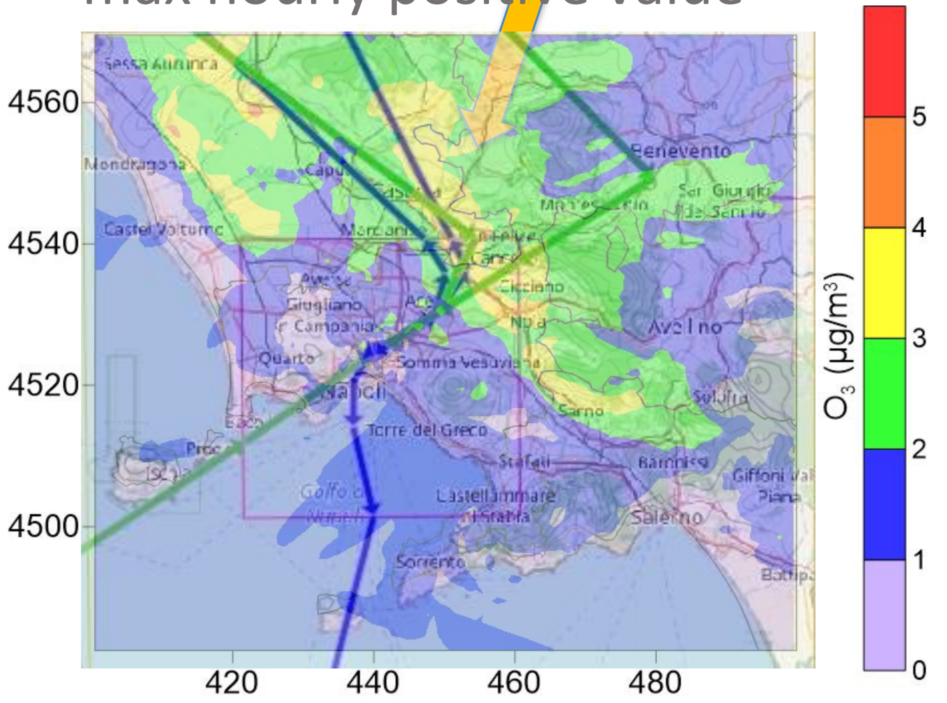
Zoom

mean value



Whole domain

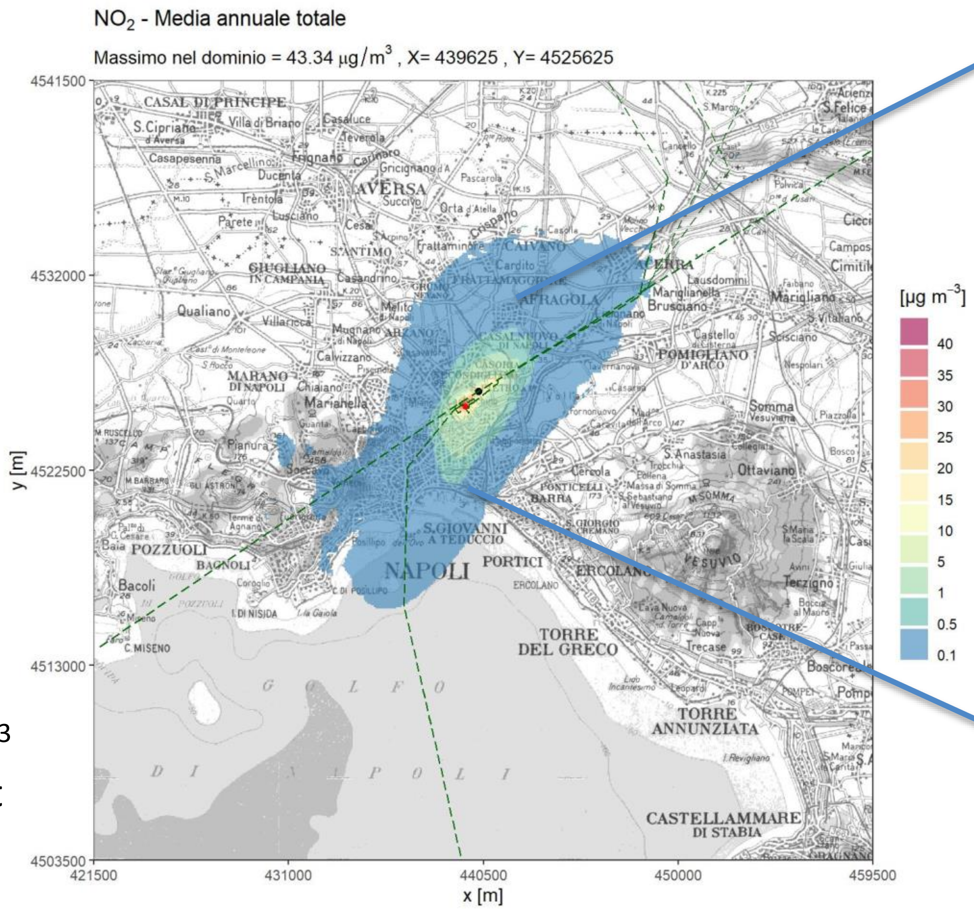
max hourly positive value

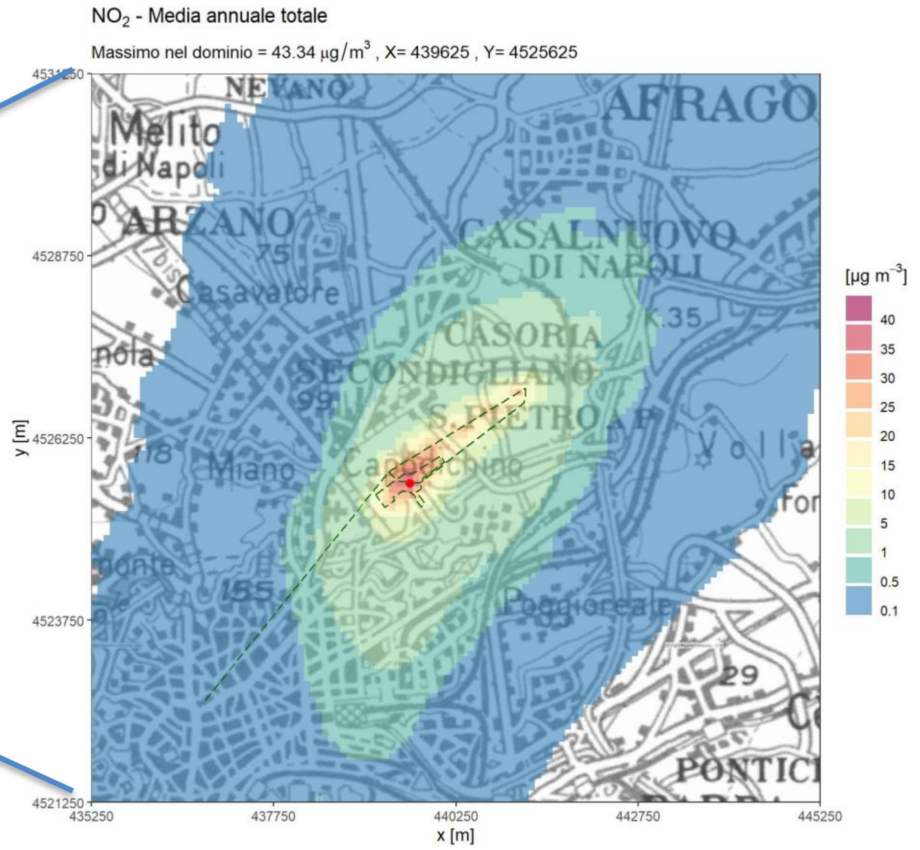


Local scale **LPM (SPRAY)**

Detailed simulation of the airport emissions

Lagrangian particle model results
NO_2 concentrations, yearly average, all the aviation activities





values > 1-5 μg/m^3 nearby the airport

maximum value of about 43 μg/m^3 located inside the airport perimeter

Obstacle resolving LPM (PMSS)

Obstacle resolving LPDM to resolve buildings nearby the airport

Investigated critical conditions:

- Light winds blowing from the airport towards the most urbanized region
- takeoffs towards South-west

Dispersion simulation

Ground level concentrations are averaged every 5 minutes

The one-hour average concentration is also computed

Case study: 05/05/2018 09:00-10:00.
6 takeoffs towards the west & 12 landings from east: one airplane movement every ~ 3.5 minutes.
Particles are emitted at 1s segment (when aviation sources are active) following the movements of the 18 airplanes

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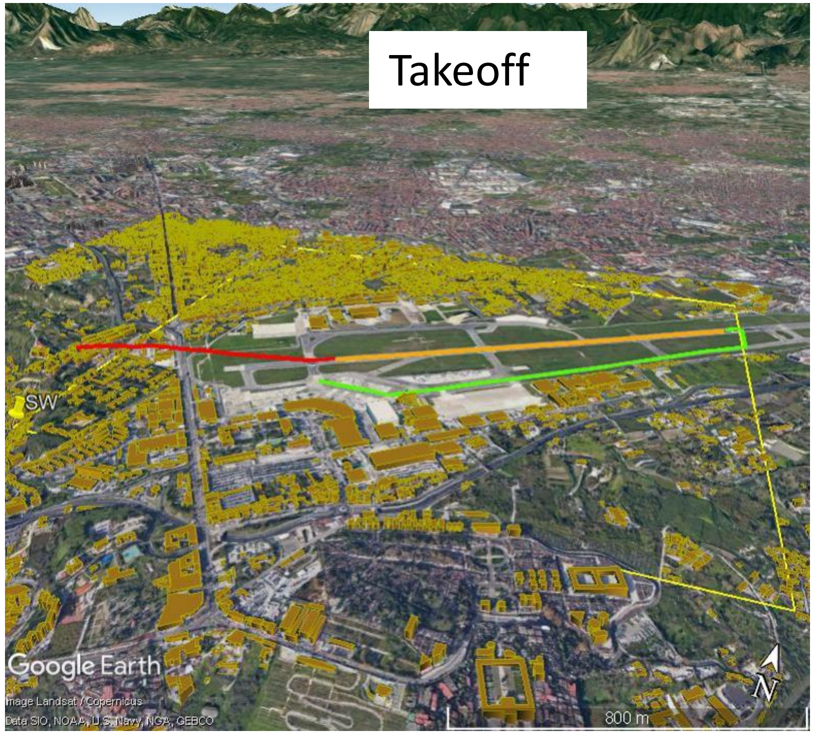
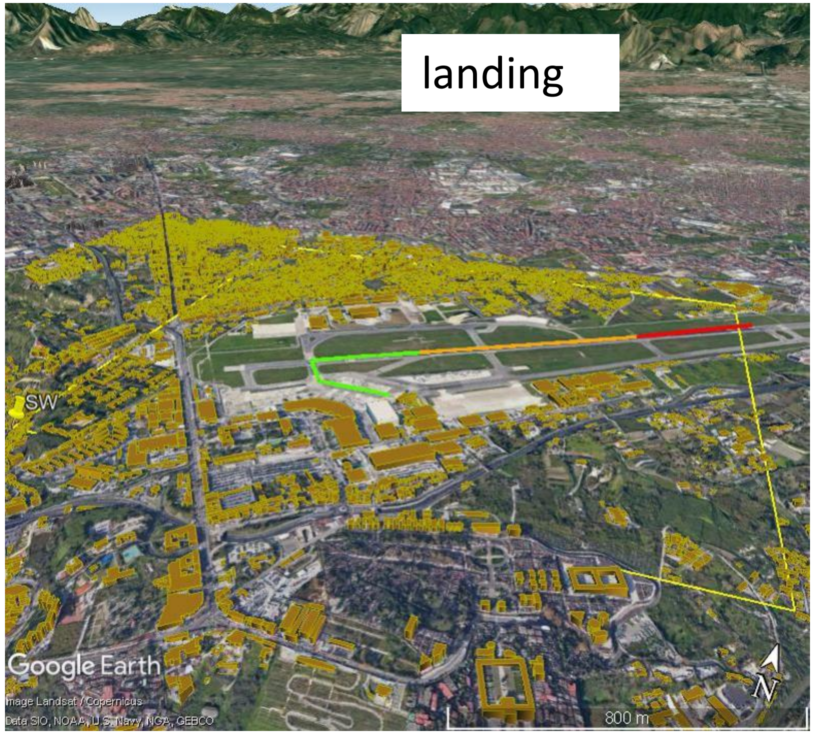
Emission features at micro scale: single aircraft source in space and time

For each takeoff different phases are considered:

- the slow movement to go from the parking position to the position to start the takeoff acceleration at the head of the runway
- the acceleration phase along the takeoff runway
- the takeoff phase with the ascending trajectory

The same for each landing, according to the opposite direction and descent operation.

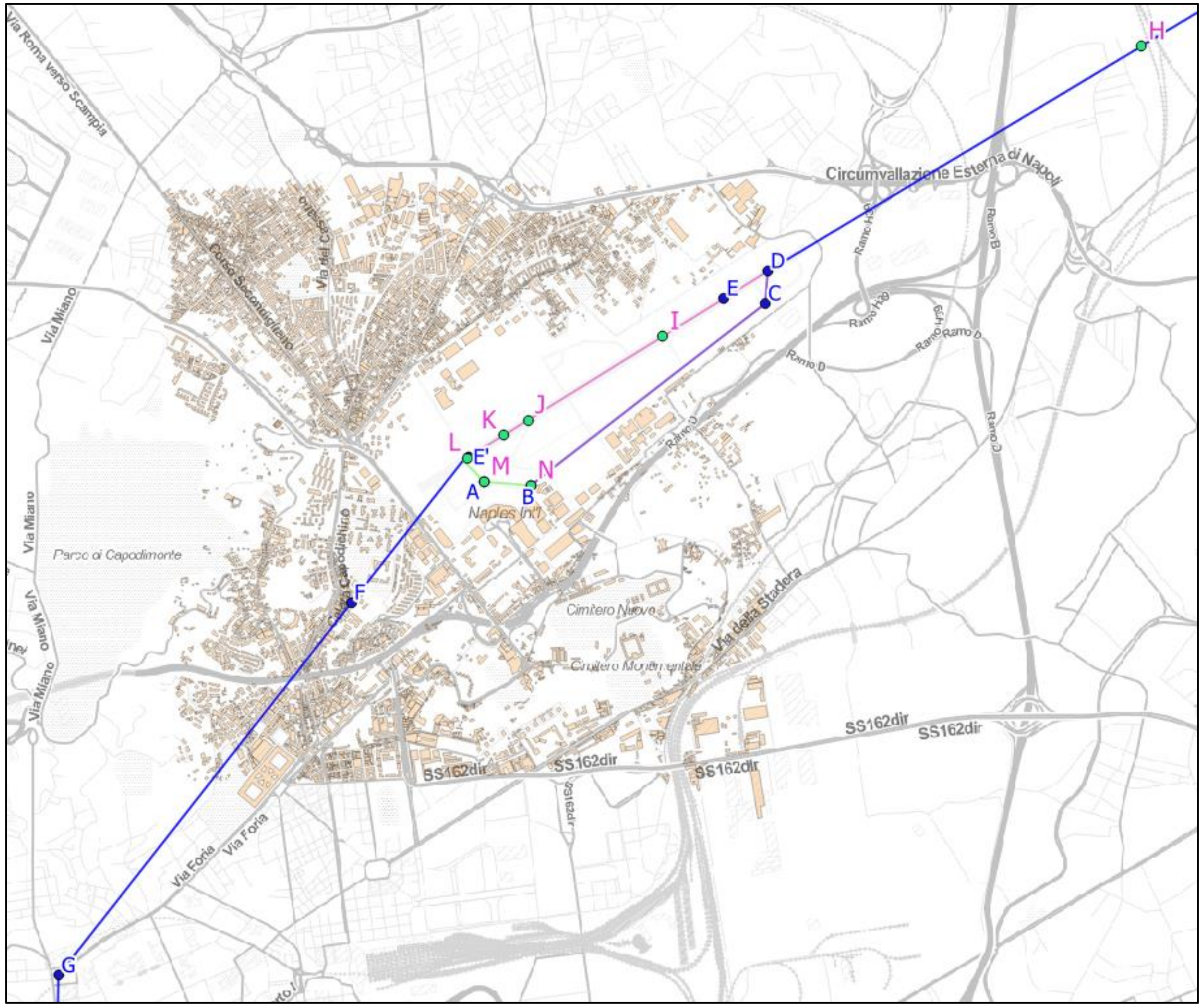




Obstacle resolving **LPM (PMSS)**

Emission features at micro scale: single aircraft source in space and time

At microscale simulations emissions are described as time/space varying along single flight trajectory.



Emission estimation for the taking off trajectories

Pollutant EF from AEM database (NOx, SOx, CO, HC, C6H6, PM2.5)

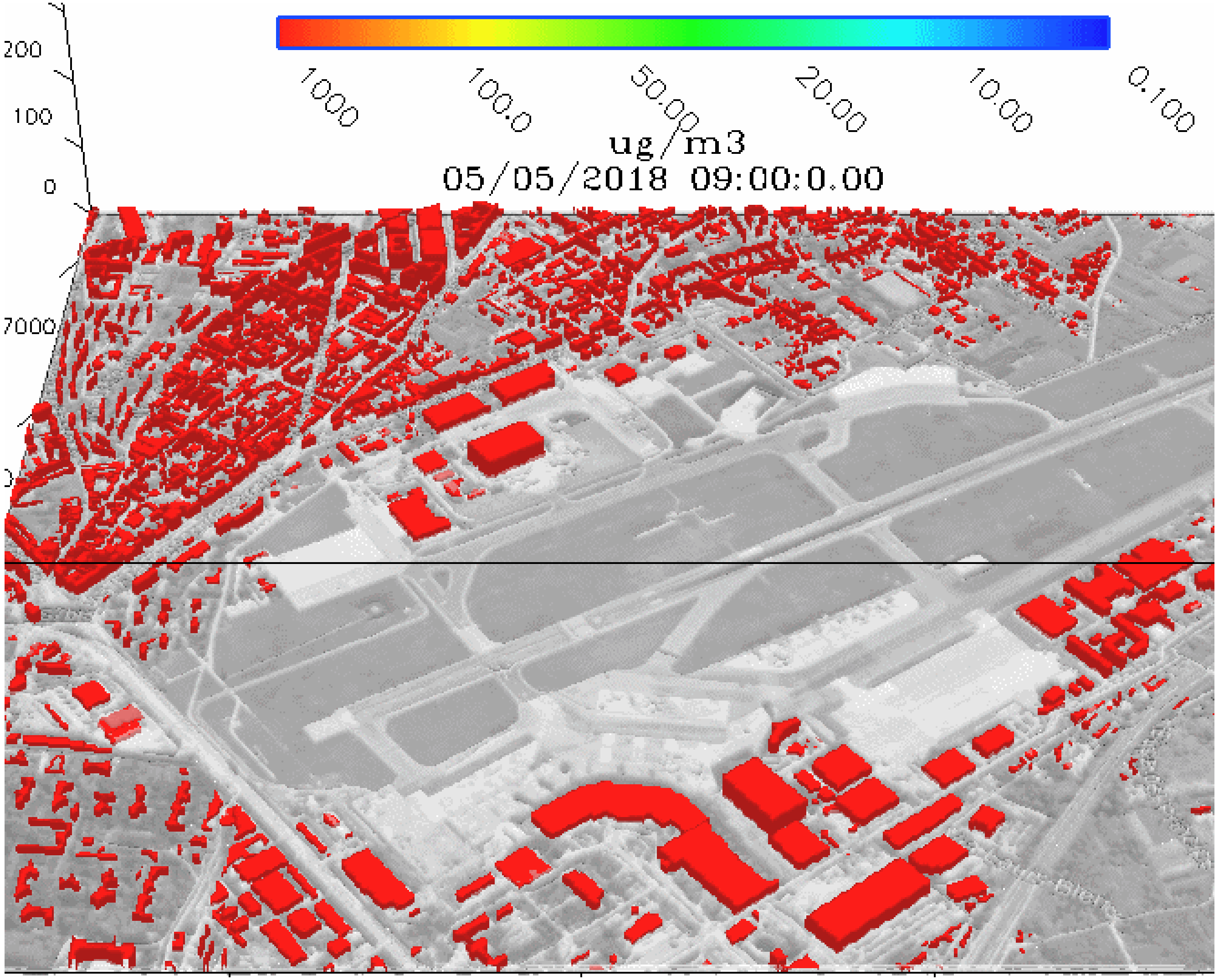
X	Y	Z [m]	VERTEX	t [s]	NOX_kg/s	SOX_kg/s	CO_kg/s	speed [m/s]
439453	4525658	76	A	1	0.001203	0.00022	0.00318	3.9
439740	4525632	76	B	74	0.001203	0.00022	0.00318	3.9
441194	4526736	76	C	537	0.001203	0.00022	0.00318	3.9
441211	4526935	76	D	588	0.001203	0.00022	0.00318	3.9
440938	4526769	76	E	669	0.001203	0.00022	0.00318	3.9
439361	4525810	76	E'	690	0.055809	0.00177	0.00112	85.1
438630	4524922	441	F	704	0.055809	0.00177	0.00112	85.1
436807	4522650	851	G	731	0.039248	0.00148	0.00109	109.0

Segment	Length [m]	tot m taxi	Phase
AB	288	m 2D	taxiout
BC	1826	m 2D	taxiout
CD	200	m 2D	taxiout
DE	319	m 2D	taxiout
EE'	1846	m 2D	takeoff
E'F	1207	m 3D	takeoff

Attitudes

Obstacle resolving LPM (PMSS)

Dispersion simulation: NOx 5 min average concentrations



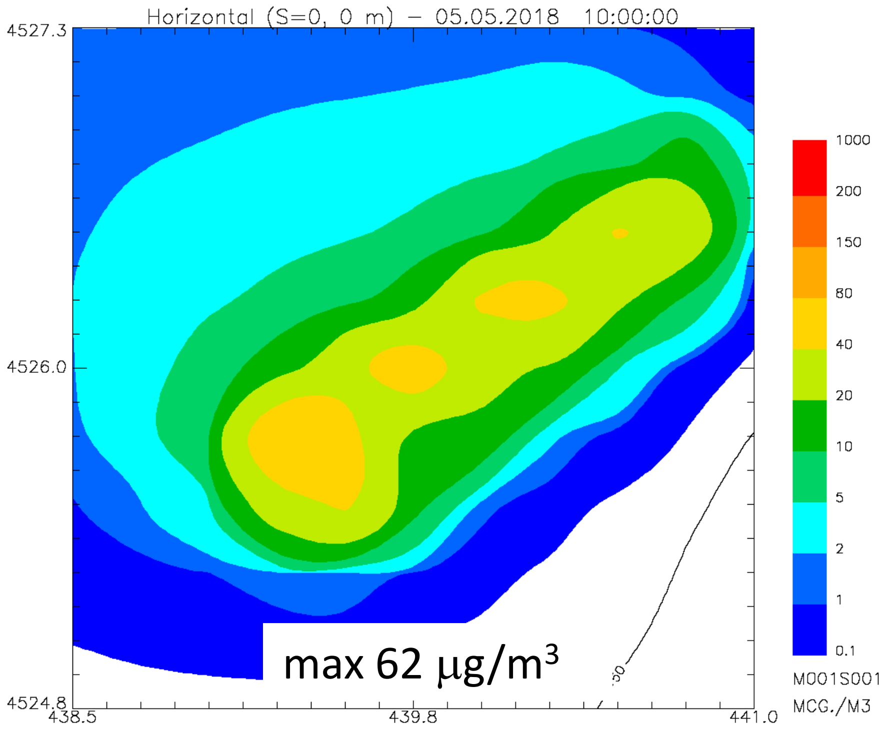
Larger values are close to the main takeoff/landing runway & the taxi lanes.
Maximum concentrations **exceed 500 μg/m^3** very close to the emissions.
The populated area is exposed to max NOx concentrations of the order of **100 μg/m^3**

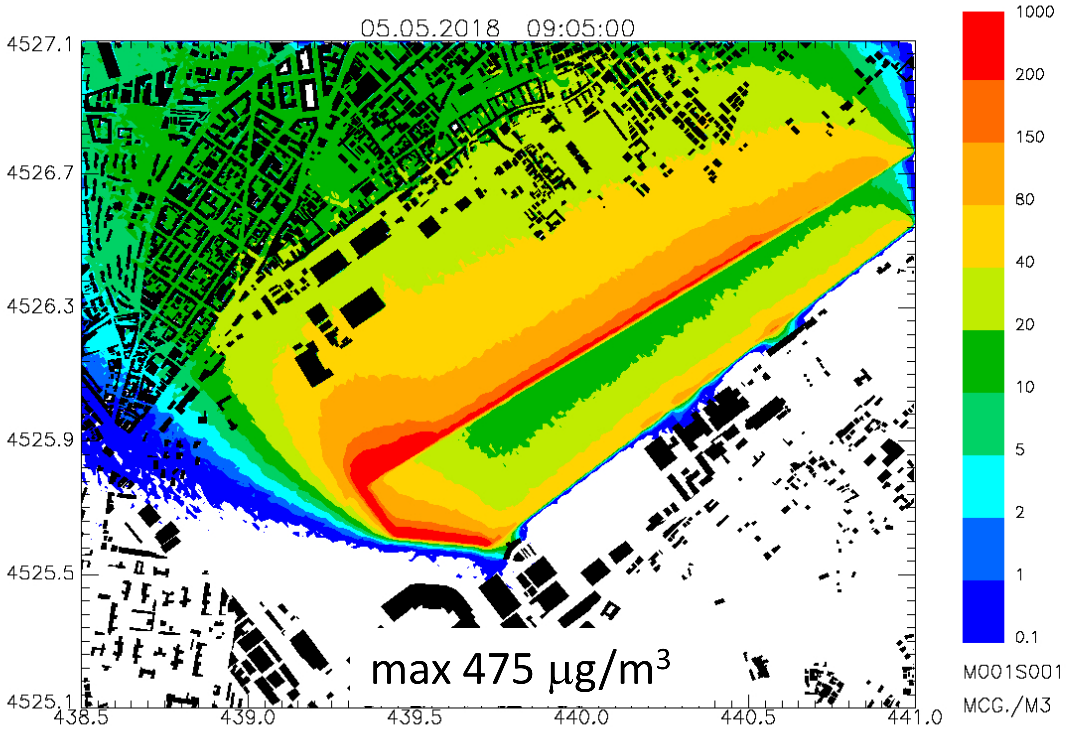
Obstacle resolving LPM (PMSS)

Dispersion simulation: NOx 1 h average concentration

Comparison of the results at "**local scale**" (250m horizontal resolution) and at "**microscale**" (5m horizontal resolution)

Same meteorological input , hourly average at 10:00, only aviation emissions, NOx





Many characteristics, both internal to the airport area and external in urbanized areas, can be described in greater detail by the microscale model

The population is exposed to a **maximum of 20-50 μg/m^3**
and passengers potentially up to **more than 450 μg/m^3**

WP2 - Relation between environment and ATM

Deliverable D2.1

Aviation impact on local environment and long term & global phenomena

Concluding remarks

The airport activities and flights emissions impact:

- Aviation emissions mainly affect air quality in areas nearby the airport (<2-3 km)
- Aviation contribution is usually not detectable from urban air quality networks
- High episodic concentrations can occur in the vicinity of the airport
- Concentration over short time periods (<1h) should be investigated by obstacle resolving modelling and short time measurements

For more details, please download deliverables:
2.1 Aviation impact on local environment and long term & global phenomena
3.1 Local and regional models integrated with weather and climate information
From CREATE web site:

https://create-project.eu/

Climate and weatheR modEls to improve ATM resiliencE and reduce its impacts

Thank you for your attention!

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