SIMBAD: una famiglia di modelli a supporto della pianificazione di politiche di qualità dell’aria multiscala

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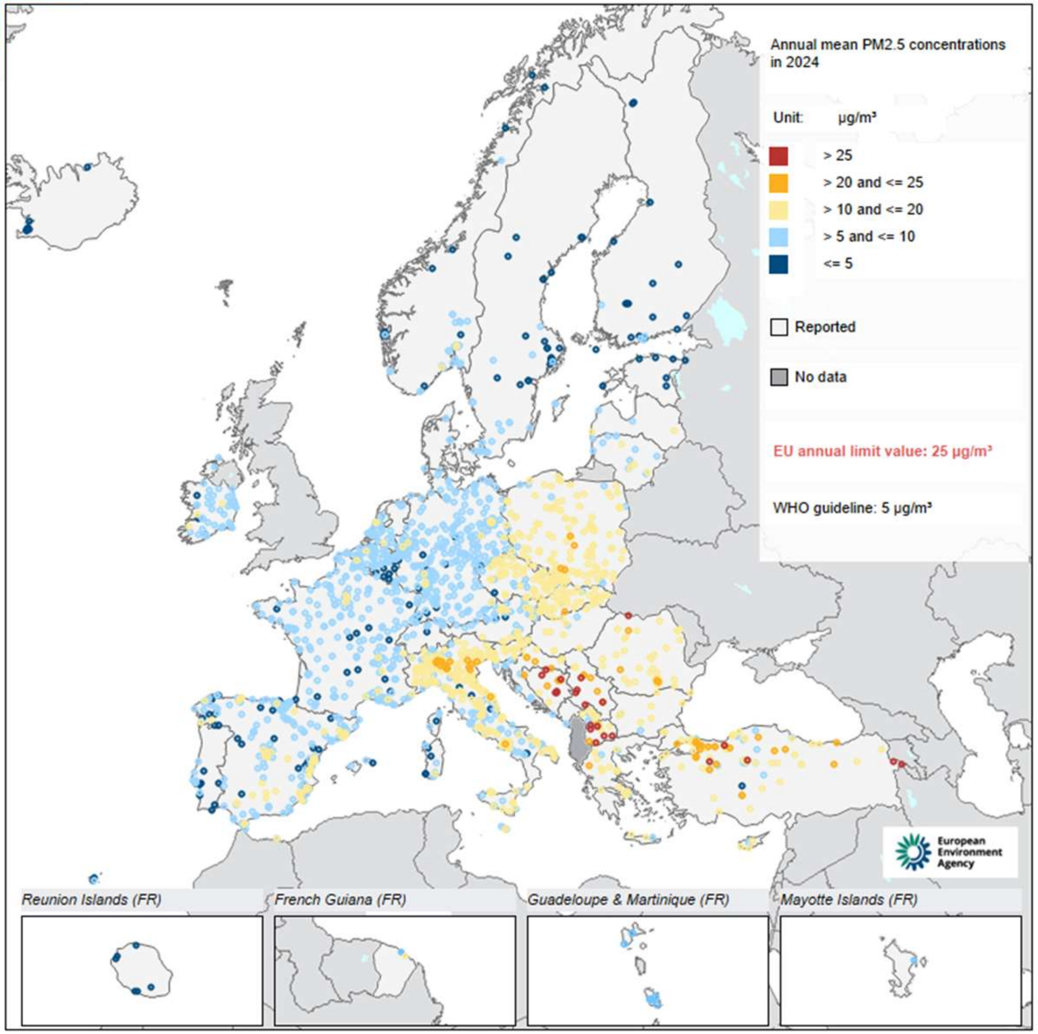
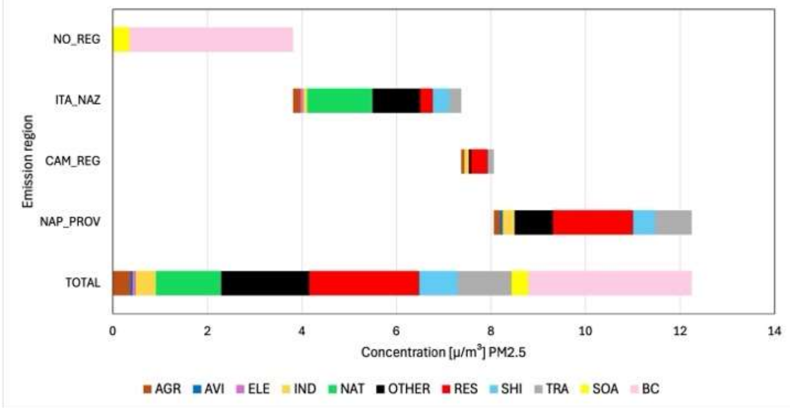
Napoli, 26-29 Maggio 2026

MOTIVATION

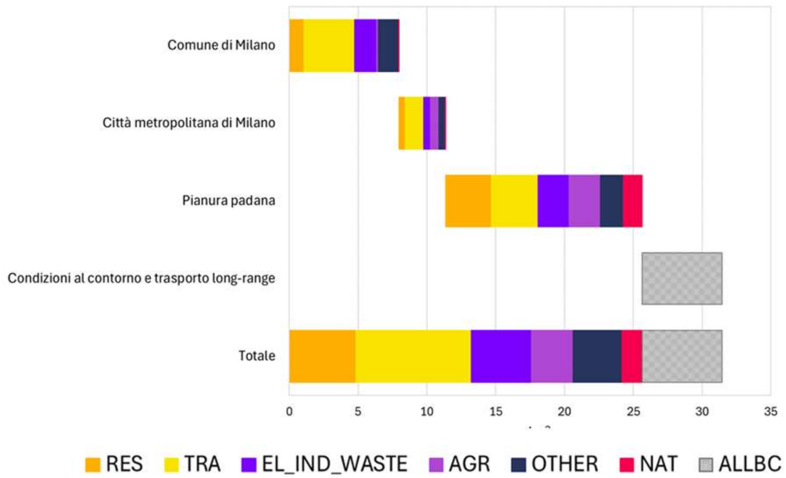


Benchmark analysis against the standards in the revised directive (EU) 2024/2881, Air quality status report 2026

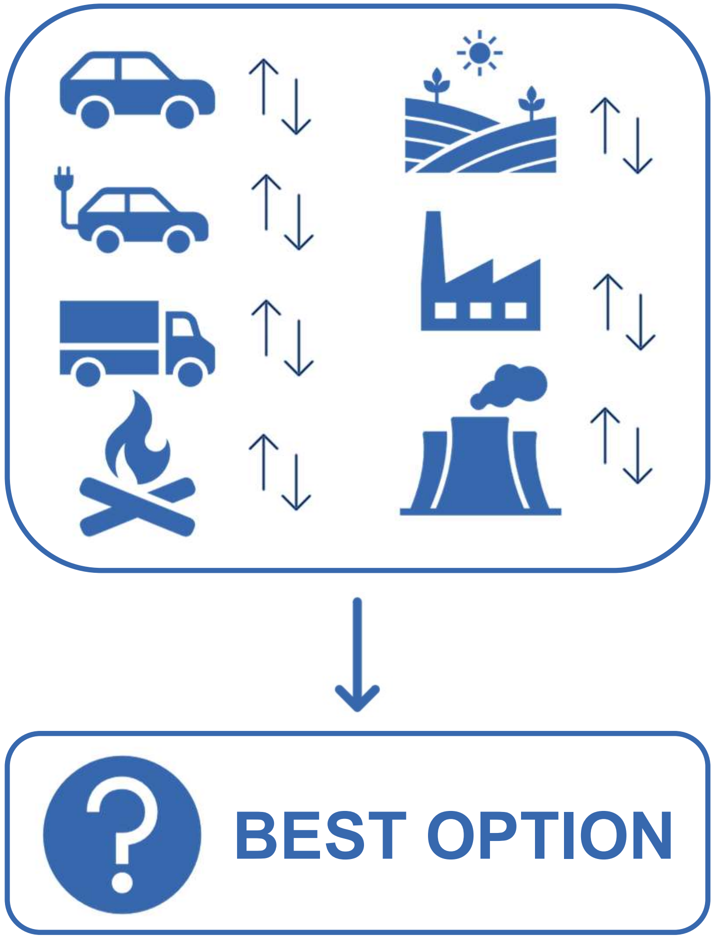
PM2.5 – Napoli Ente Ferrovie



PM10 - Milano Pascal



MOTIVATION



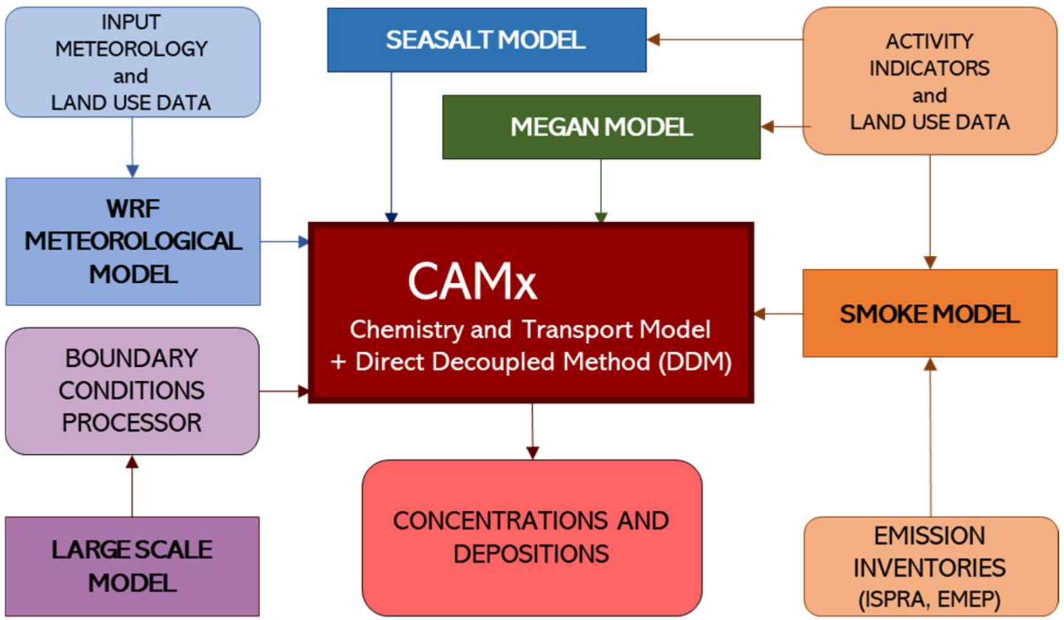
To find the **optimal policy** there is the need to **investigate multiple scenarios**

Compared to brute-force simulations with classical CTMs, **a simplified model offers clear advantages as a fast and efficient screening tool**
(less computational time and resources)

SIMBAD: **SI**mplified **M**odel **BA**sed on **D**DM (– **R**egional **U**rban **M**odel)

A simplified **emission-concentration model** derived from the multi-scale photochemical model **CAMx** implemented using the **Direct Decoupled Method** (DDM)

Concentrations in SIMBAD scenarios are computed via **a first-order Taylor expansion** using **CAMx/DDM sensitivities** for selected sectors/areas/precursors.



***CAMx** Decoupled **D**irect **M**ethod*
(Dunker et al., 2002)

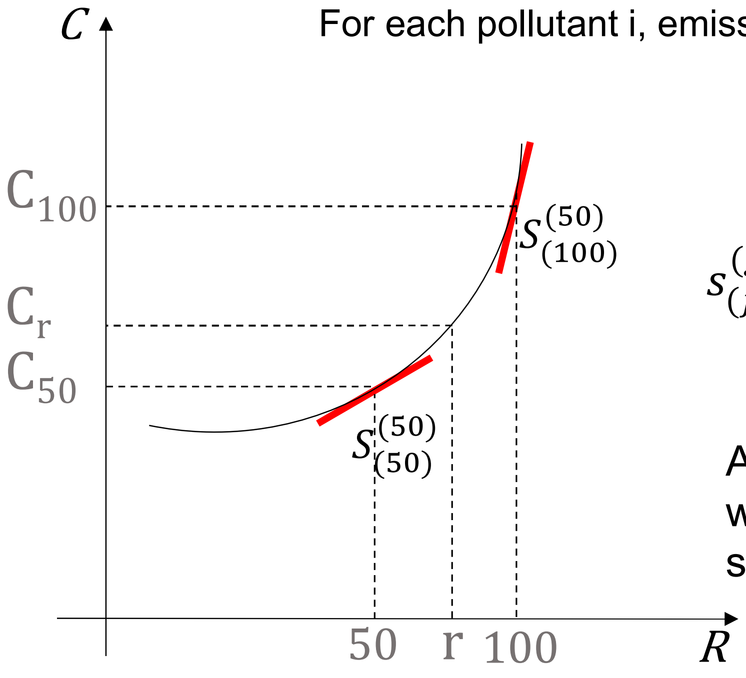
- Formulation coherent with CAMx model
- Adapts to multiple purposes
- Computes sensitivity of concentration to emission changes

SIMBAD model formulation

$$c_{p(r)} = \overline{\omega_{p}}_{(100)}\left(c_{p(100)} + \sum_{i=1}^{N_{pre}}\sum_{j=1}^{N_{sec}}\sum_{k=1}^{N_{reg}} \lambda_{i,j,k}\, s_{p,i,j,k}{}^{(50)}_{(100)}\right) + \overline{\omega_{p}}_{(50)}\left(c_{p(50)} + \sum_{i=1}^{N_{pre}}\sum_{j=1}^{N_{sec}}\sum_{k=1}^{N_{reg}} (1+\lambda_{i,j,k})\, s_{p,i,j,k}{}^{(50)}_{(50)}\right)$$

For each pollutant i, emission sources group *j* and area *k*

$$\boxed{s_{(f)}^{(g)} \quad \frac{\partial c_p}{\partial e} \longrightarrow \frac{\Delta c_p}{\Delta e}\cdot \Delta e}$$



$s_{(f)}^{(g)}$ → Perturbation

$s_{(f)}^{(g)}$ → Unperturbed state

A 50% emission perturbation was chosen to calculate sensitivity coefficients

Variation coefficient $\quad r_{i,j,k} = \dfrac{Emix(scenario)}{Emix(base)}\,\%$

Perturbation coefficient $\quad \lambda_{i,j,k} = \dfrac{100 - r_{i,j,k}}{50}$

$r_i = 100\% \qquad \lambda_i = 0$

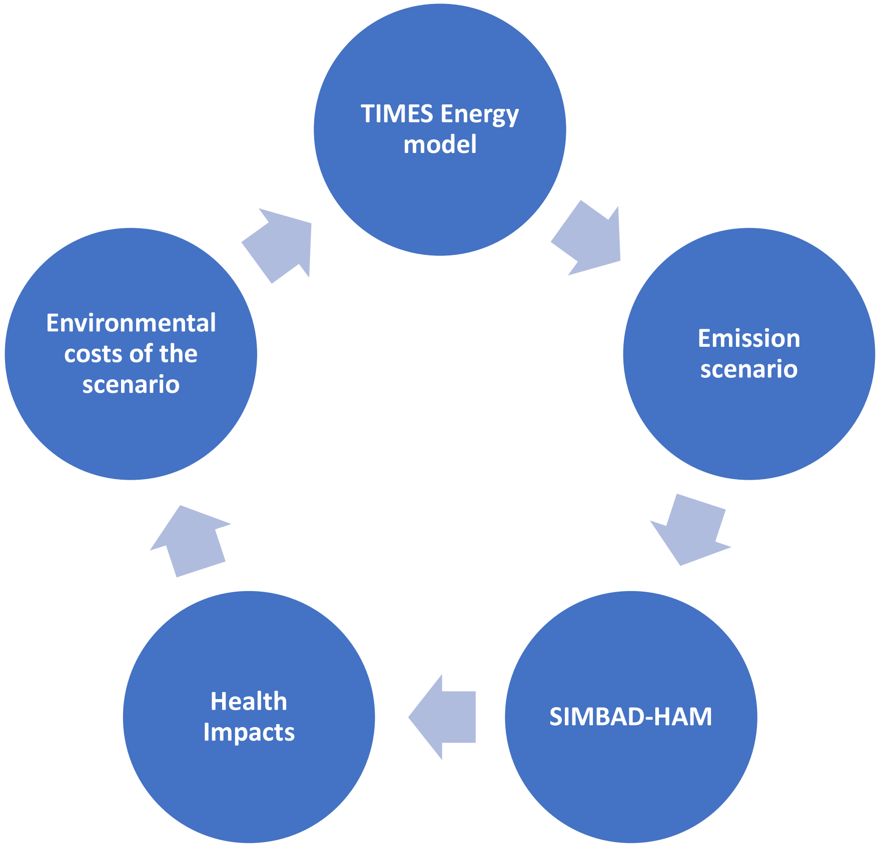
$r_i = 60\% \qquad \lambda_i = 0.8$

$r_i = 50\% \qquad \lambda_i = 1$

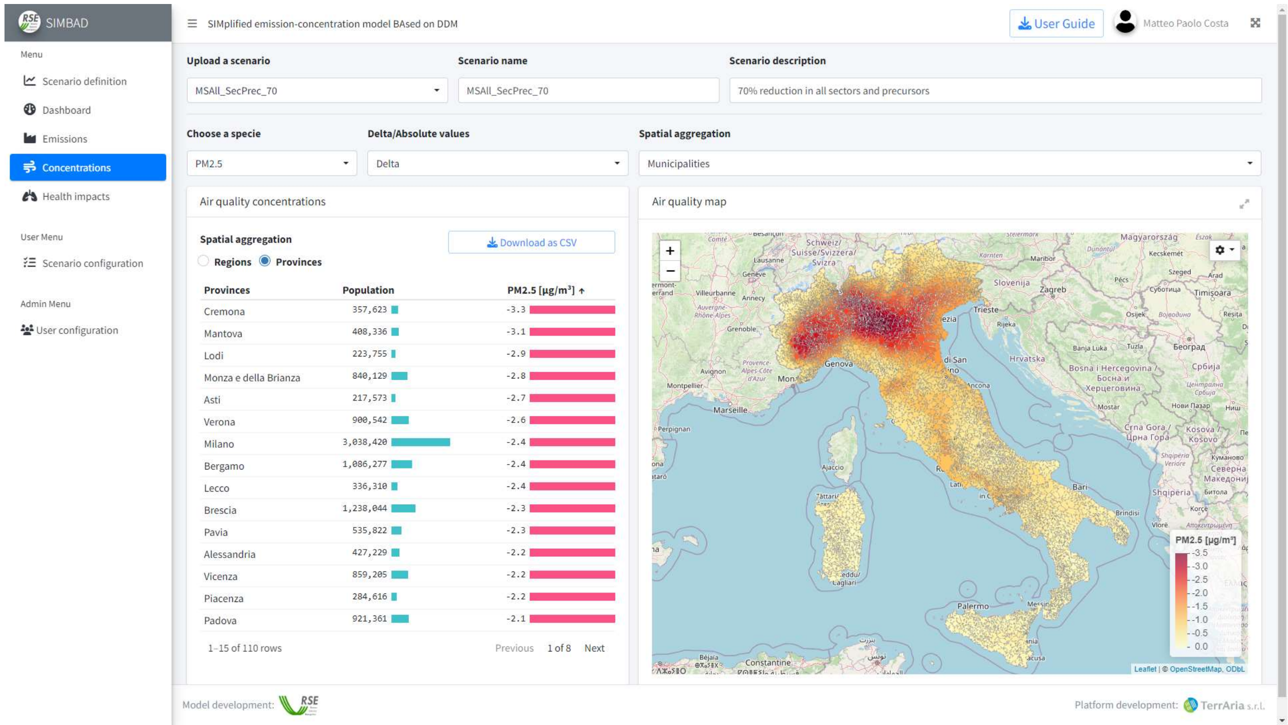
SIMBAD-HAM

SIMBAD-HAM: SImplified Model BAsed on DDM – HArmonised Model

Energy planning applications



Web user interface



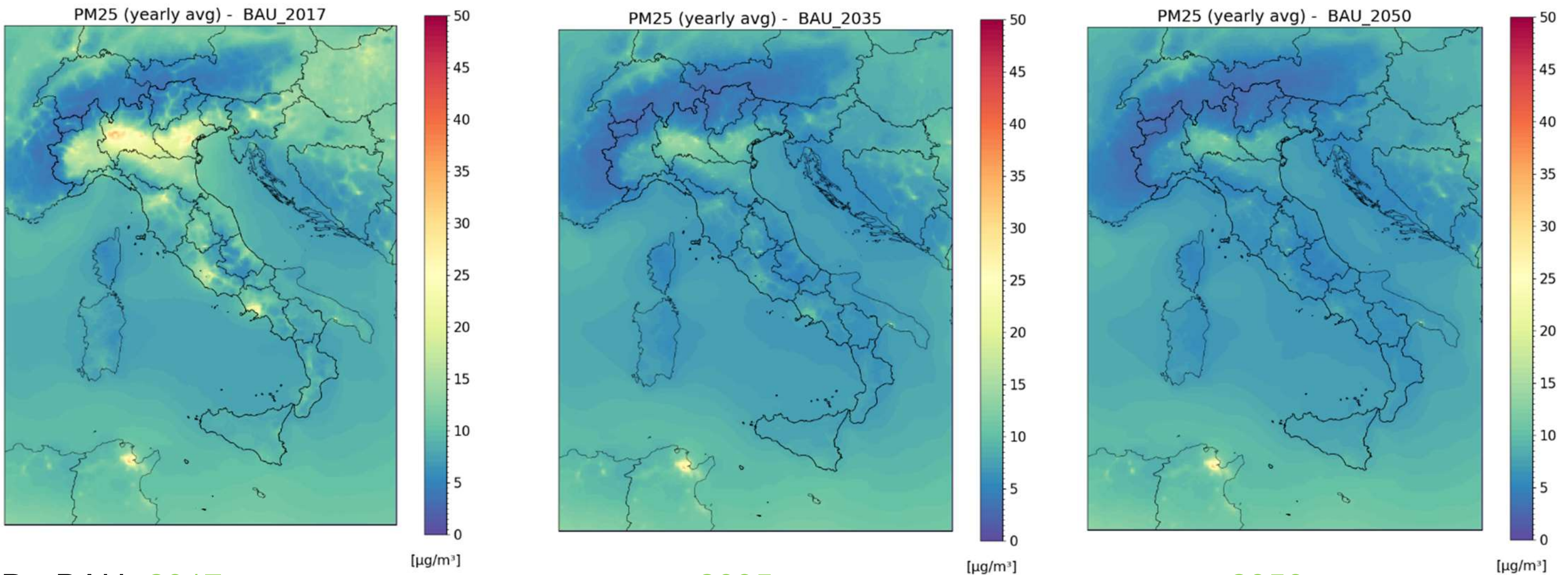
SIMBAD HAM – Modelling Setup

- Yearly simulation for meteorological year 2017
- Pollutants: NO_2, PM2.5, PM10, SO_2, NH_3, EC, O_3
- Indicators:
  - yearly and daily mean concentrations (exceedances)
  - HIA indicators (e.g. YOLL)
  - HIA costs
- Sensitivity coefficients computed for each cell at hourly time step for:
  - 1 area -> Italy
  - 7 emission sectors: MS01, MS02 BIO/NOBIO, MS0304, MS07 (NOEV/EV), MS10
  - 5 precursor species: NO_X, SO_2, NH_3, VOC, PPM
- Dynamical evaluation in time
  - 3 reference years: 2017 – 2030 – 2050
  - B.A.U. based on NAPCP proposed by M.S. in 2019 (IIASA – 2nd CAO report)

SIMBAD - BAU	2017		2035	2050
SIMBAD - SCEN	2017		2035	2050
CAMx	2017	2030		2050

SIMBAD HAM - Case Studies

PM2.5 - Yearly mean concentration
Business As Usual (BAU) scenarios



SIMBAD - BAU 2017 2035 2050

CAMx 2017 2030 2050

SIMBAD HAM - Case Studies

Additional emission reduction scenarios

Scenario	Anno	Sector	Emission reduction
2017_SCE70_TRA	2017	Road transport (MS07)	30%
2017_SCE70_RES_BIOM	2017	Biomass burning (MS02)	30%
2017_SCE70_AGR	2017	Agriculture (MS10)	30%
2035_SCE70_TRA	2035	Road transport (MS07)	30%
2035_SCE70_RES_BIOM	2035	Biomass burning (MS02)	30%
2035_SCE70_AGR	2035	Agriculture (MS10)	30%
2050_SCE70_TRA	2050	Road transport (MS07)	30%
2050_SCE70_RES_BIOM	2050	Biomass burning (MS02)	30%
2050_SCE70_AGR	2050	Agriculture (MS10)	30%

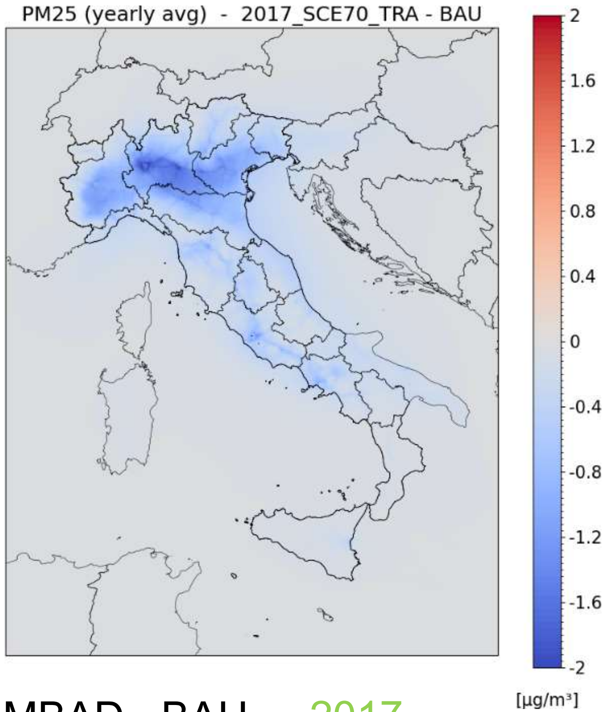
SIMBAD - BAU 2017 2035 2050

SIMBAD - SCEN 2017 2035 2050

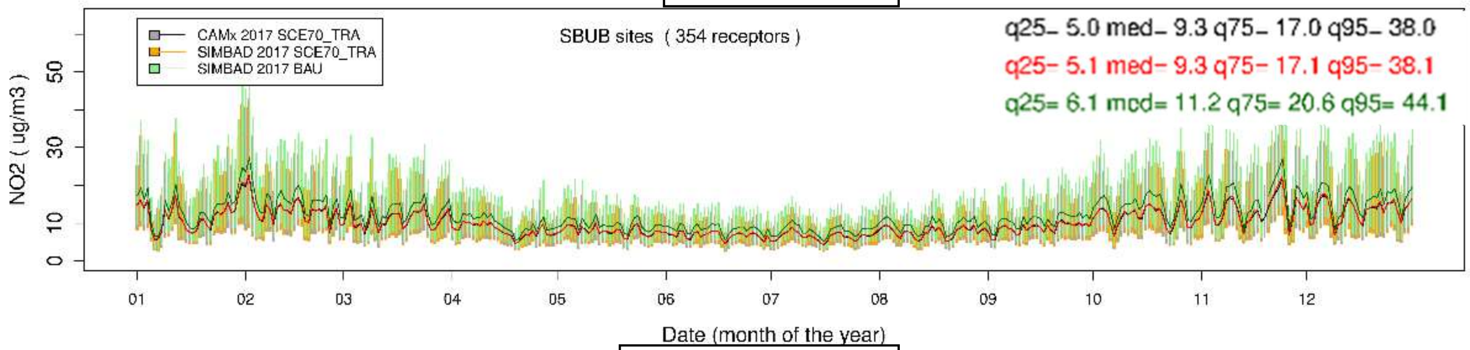
CAMx 2017 2030 2050

SIMBAD HAM - Case Studies

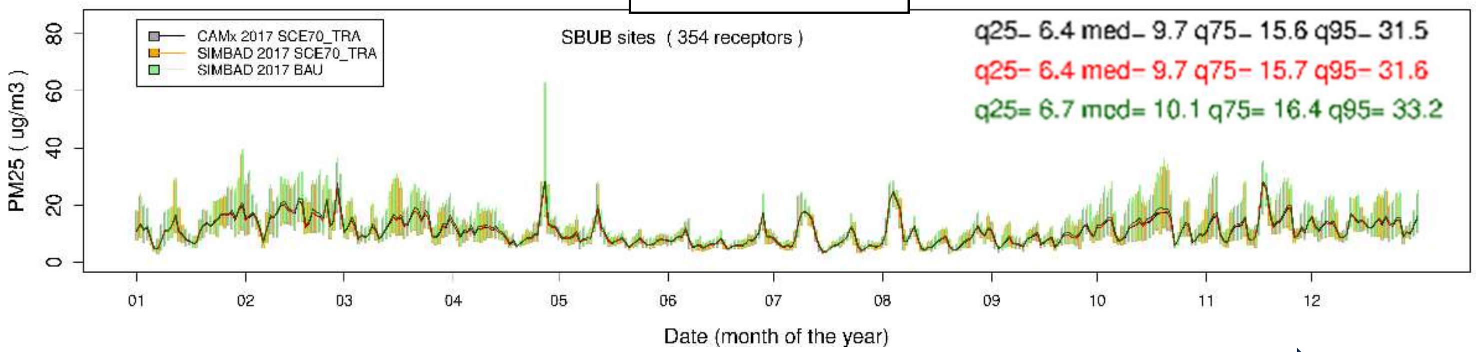
PM2.5 - Yearly mean concentration
Road transport - 2017



NO$_2$



PM2.5



SIMBAD - BAU 2017

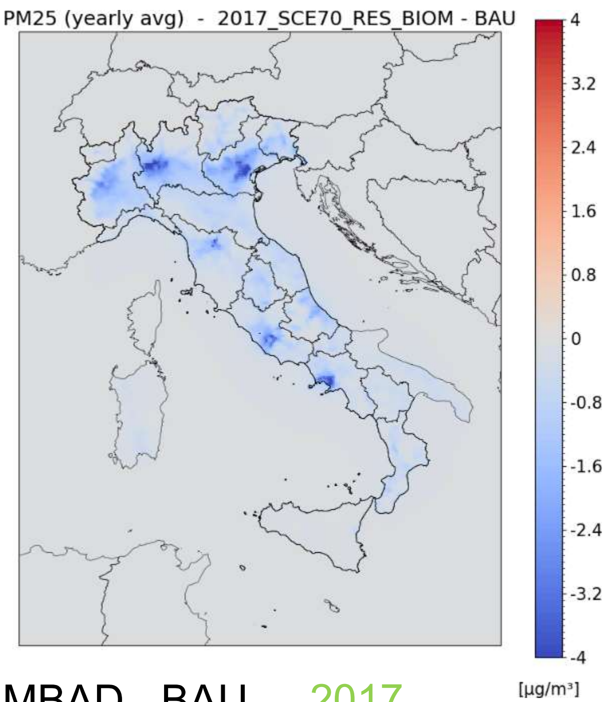
SIMBAD - SCEN 2017

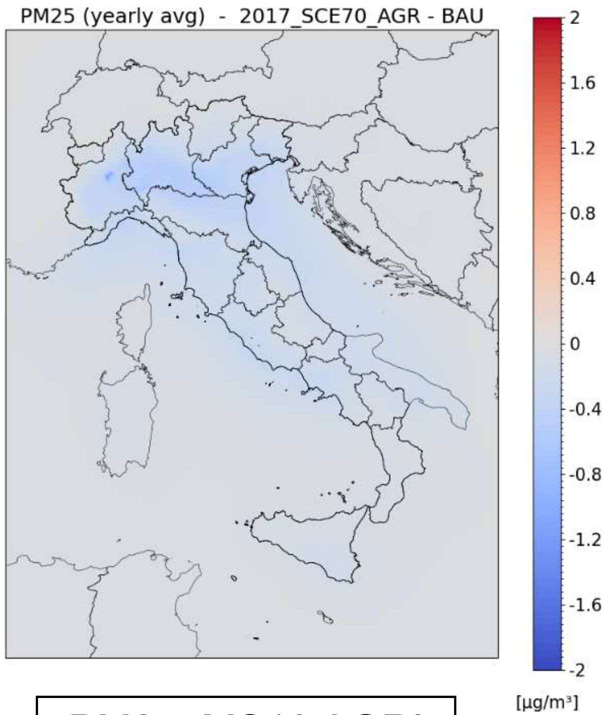
CAMx 2017

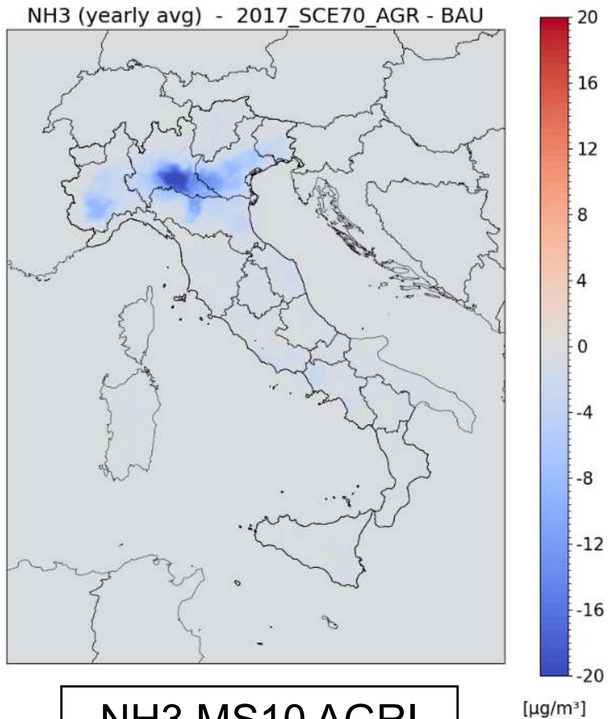
SIMBAD HAM - Case Studies

Yearly mean concentration
Biomass burning and Agriculture - 2017

PM2.5 MS02 BIO







SIMBAD - BAU 2017

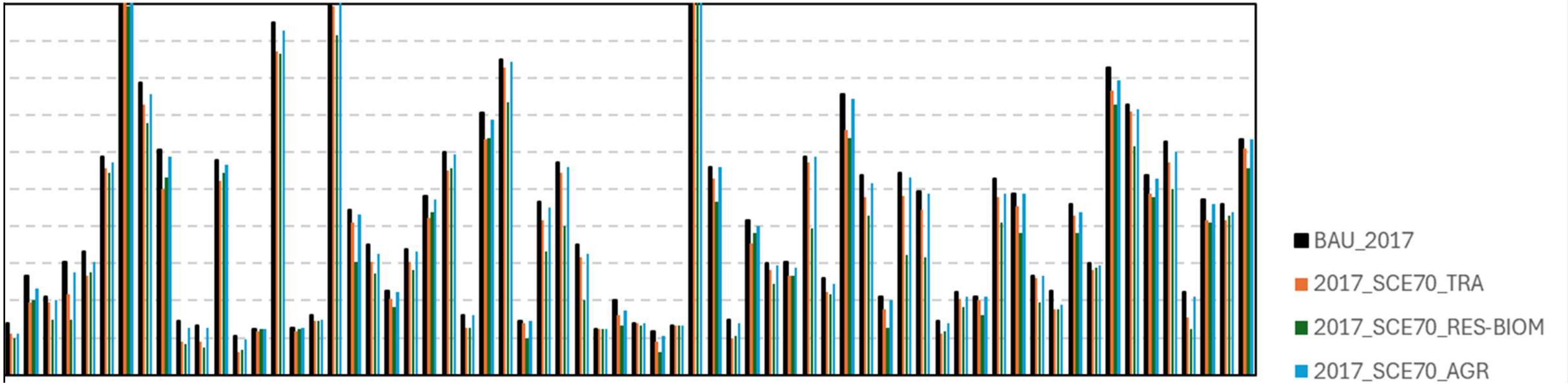
SIMBAD - SCEN 2017

PM2.5 MS10 AGRI

NH3 MS10 AGRI

SIMBAD HAM - Case Studies

PM2.5 - Daily mean concentration exceedances
Road transport, Biomass burning and Agriculture - 2017



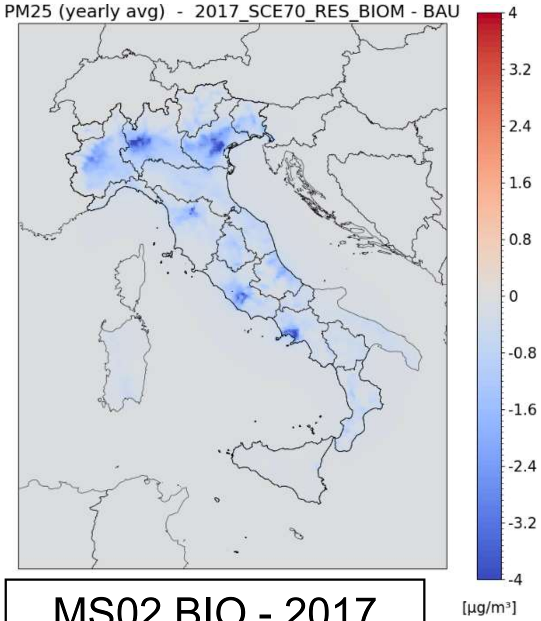
SIMBAD - BAU 2017

SIMBAD - SCEN 2017

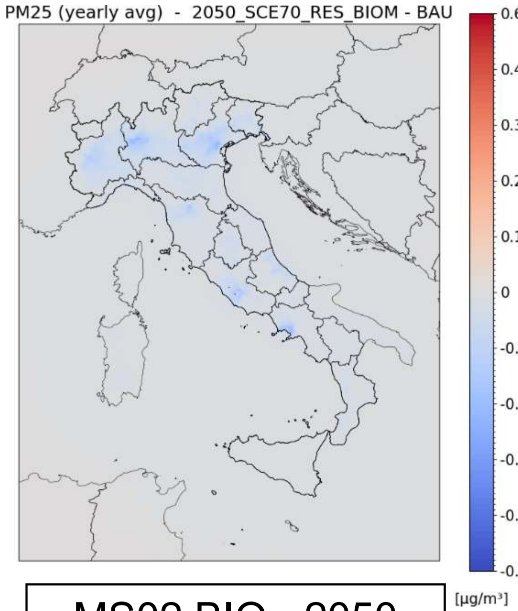
Airbase SBUB sites with more the 18 days exceeding 25 $\mu g/m^3$ in BAU_2017

SIMBAD ITA - Case Studies

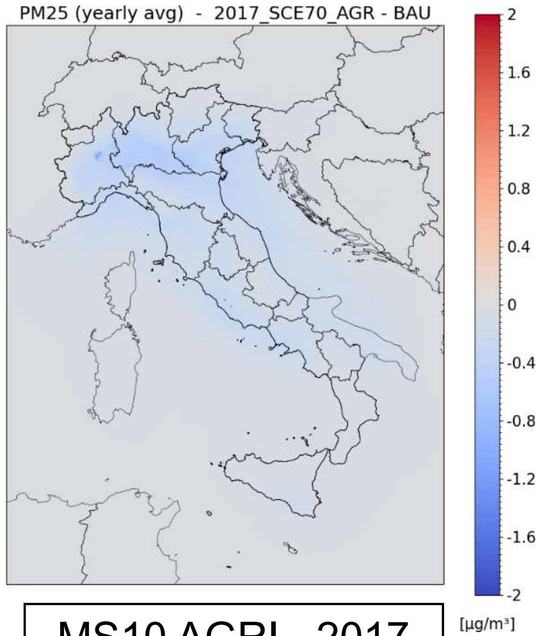
PM2.5 - Yearly mean concentration
Biomass burning and Agriculture – 2017 and 2050



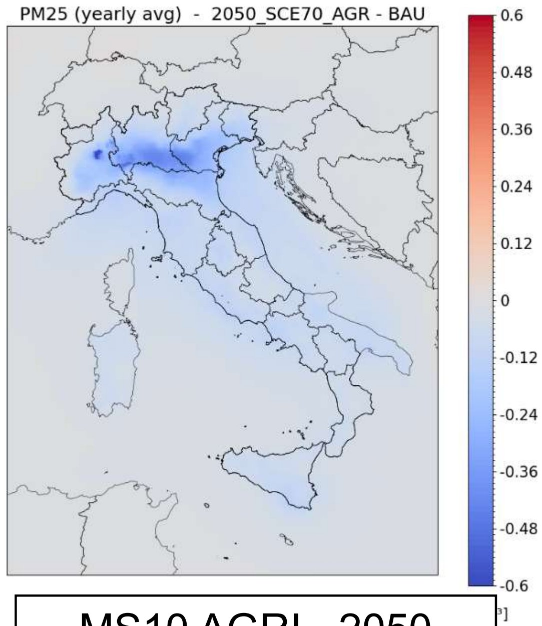
MS02 BIO - 2017



MS02 BIO - 2050



MS10 AGRI - 2017



MS10 AGRI - 2050

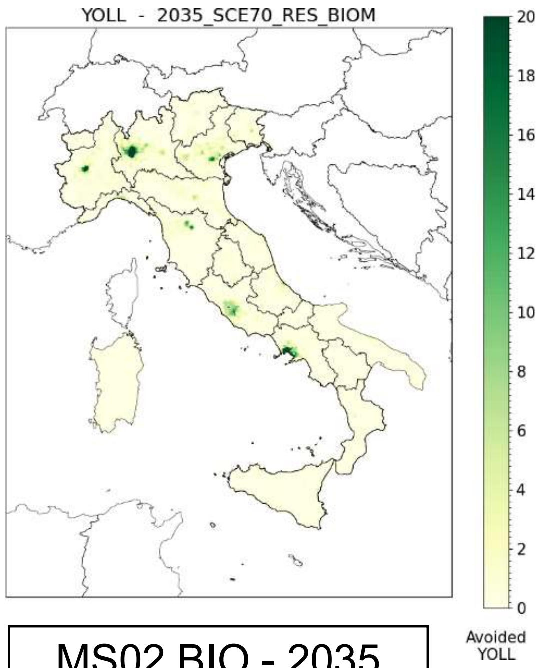
SIMBAD - BAU 2017 2050

SIMBAD - SCEN 2017 2050

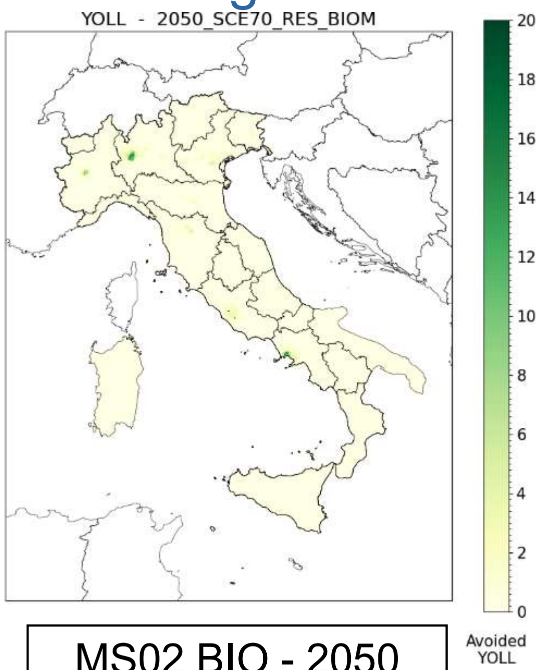
SIMBAD HAM - Case Studies

YOLL

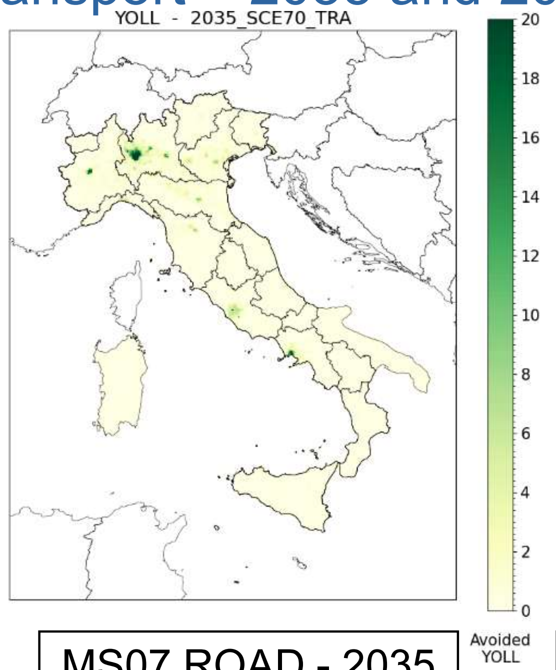
Biomass burning and Road transport – 2035 and 2050



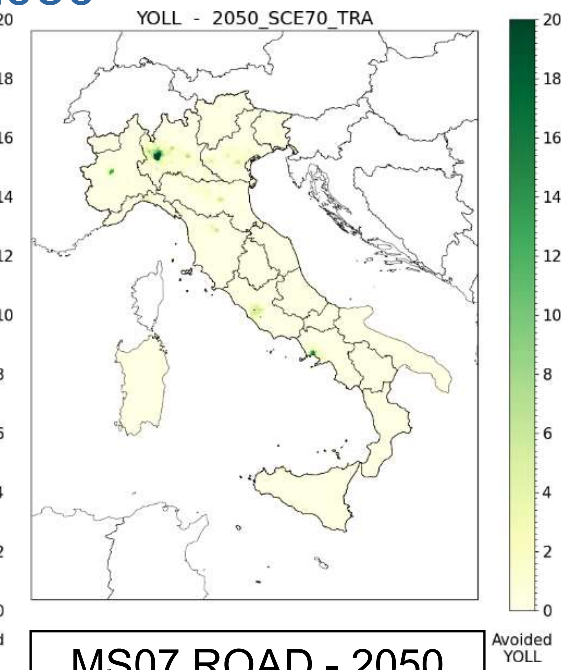
MS02 BIO - 2035



MS02 BIO - 2050



MS07 ROAD - 2035

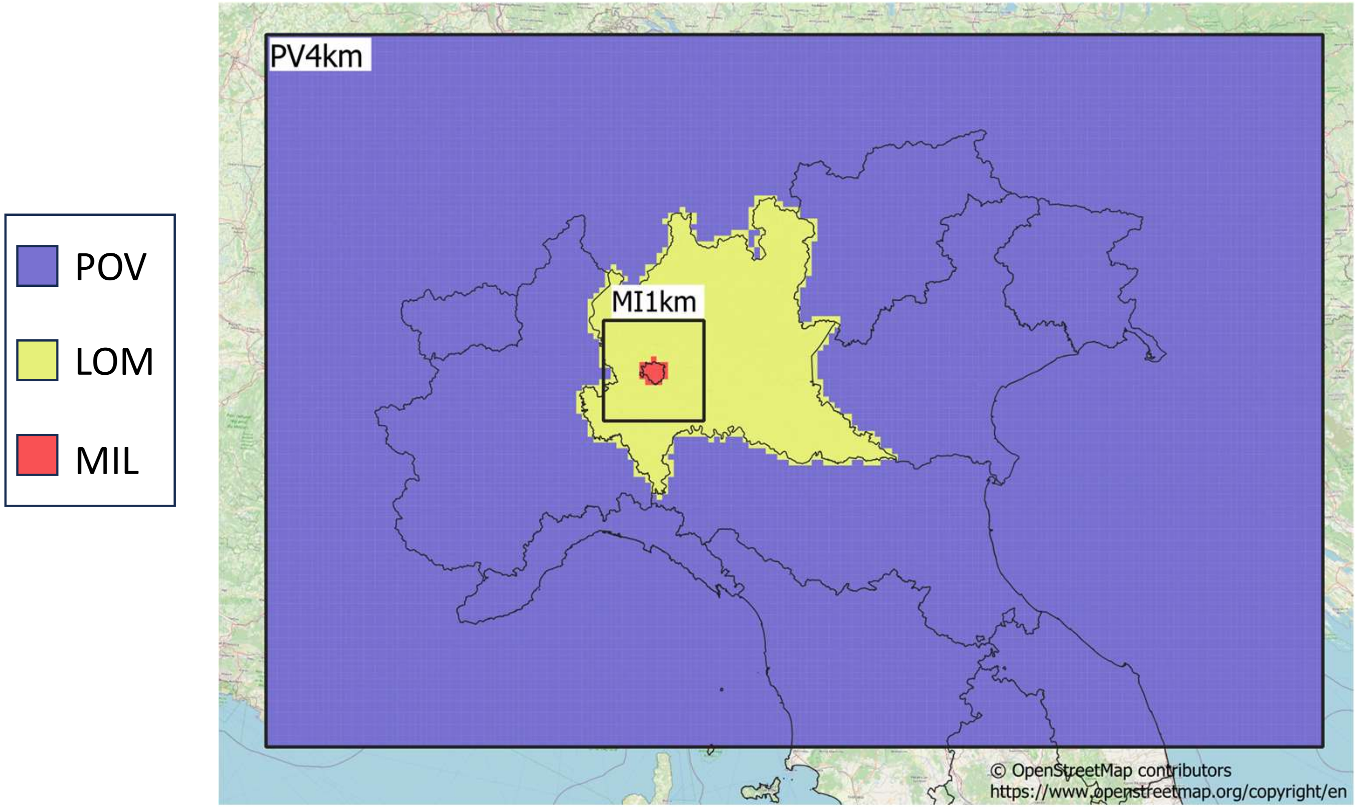


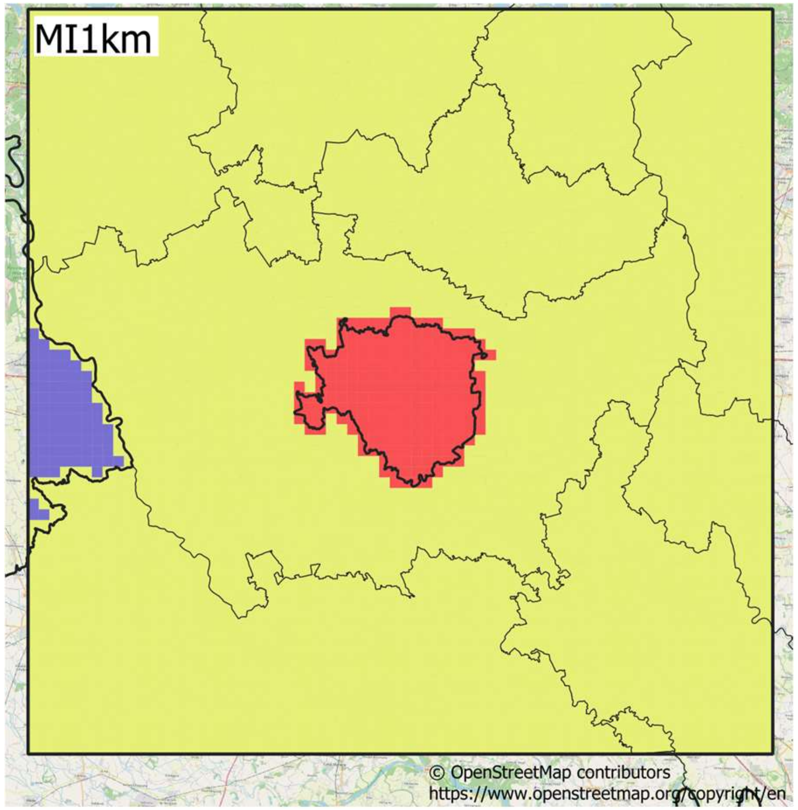
MS07 ROAD - 2050

SIMBAD - BAU	2035	2050
SIMBAD - SCEN	2050	2050

SIMBAD-RUM: Case Study

- Yearly simulation for 2017
- Sensitivity coefficients computed for each cell at hourly time step for:
  - 3 areas, 6 emission sectors and 5 precursor species





SIMBAD-RUM: Case Study

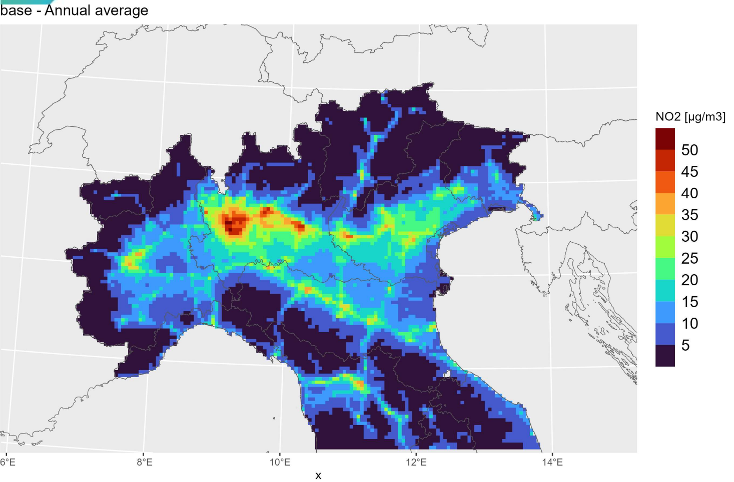
Emission sectors	Description
07HDV_EX	Exhaust emissions of heavy and light duty vehicles
07CAR_EX	Exhaust emissions of cars and motorcycles/mopeds
07NEX_RES	Non exhaust emissions (only MI1km) and resuspension
02BIO	Residential heating: Biomass Burning
02OTH	Residential heating: Other fuels
10AGR	Agriculture

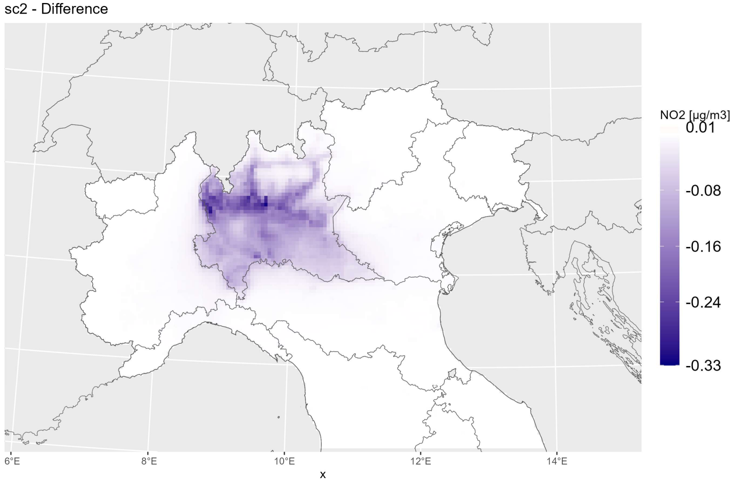
Emission variation is considered for the following precursors species:

- NOx
- SO_2
- NH_3
- VOC
- PM2.5 and PM Coarse (Primary)

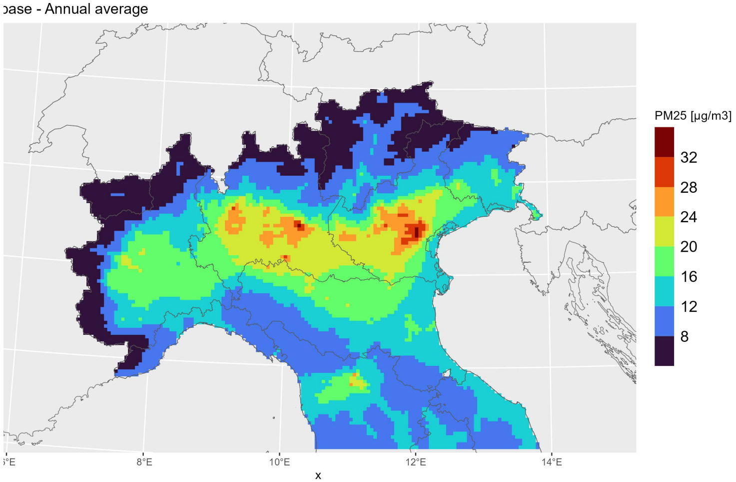
SIMBAD-RUM: results

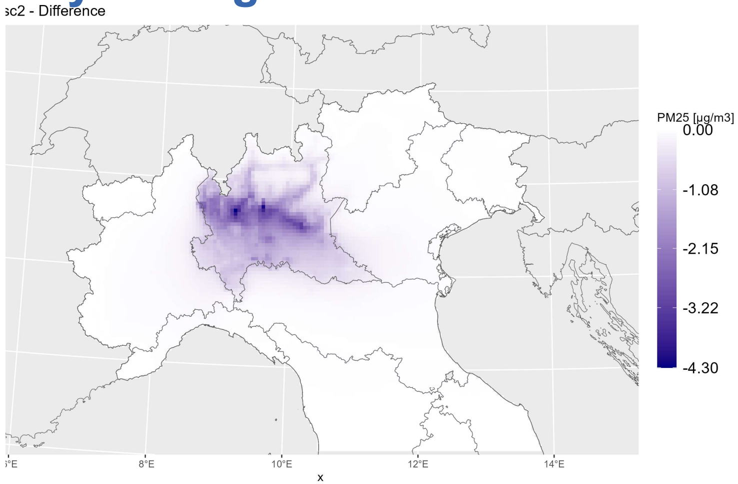
NO_2 – Yearly Average





PM2.5 – Yearly Average





- 50% reduction
- All precursors
- 02BIO, **LOM**

SIMBAD-RUM (Regional Urban Model)

Examples of multiscale scenarios

Code	Description
SC1	Moderate electrification of the light-duty vehicle fleet, at all spatial scales.
SC2	High electrification of the light-duty vehicle fleet, at local scale.
SC3	Reduction in travel demand. Heavy-duty vehicles: regional scale. Light-duty vehicles: local scale
SC4	Combination of measures from SC1 and SC3.
SC5	Reduction in biomass-based residential heating and agriculture sectors: all scales.

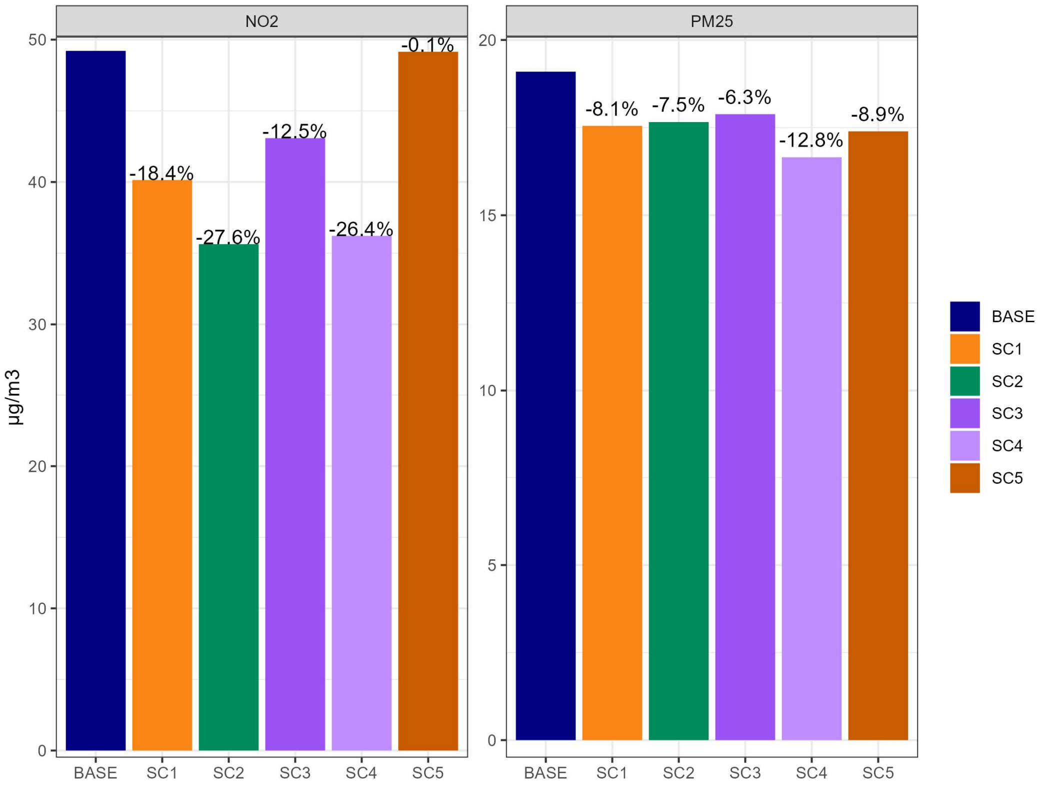
	TRA_EX_HDV			TRA_EX_LDV			RESUSP			TRA_NOEX			RES_BIOM			AGR		
	POV	LOM	MIL	POV	LOM	MIL	POV	LOM	MIL	POV	LOM	MIL	POV	LOM	MIL	POV	LOM	MIL
SC1	0	0	0	-40	-40	-40	0	0	0	-3.1	-3.1	-3.1	0	0	0	0	0	0
SC2	0	0	0	0	0	-80	0	0	0	0	0	-6.2	0	0	0	0	0	0
SC3	-10	-10	0	0	-10	-30	-5.7	-10	-13	-2.6	-10	-22.2	0	0	0	0	0	0
SC4	-10	-10	0	-40	-45	-60	-5.7	-7.8	-10.9	-5.7	-12.7	-21.2	0	0	0	0	0	0
SC5	0	0	0	0	0	0	0	0	0	0	0	0	-30	-30	-30	-30	-30	-30

SIMBAD-RUM (Regional Urban Model)

Milano Pascal receptor – Yearly mean concentration – MIL 1 km grid

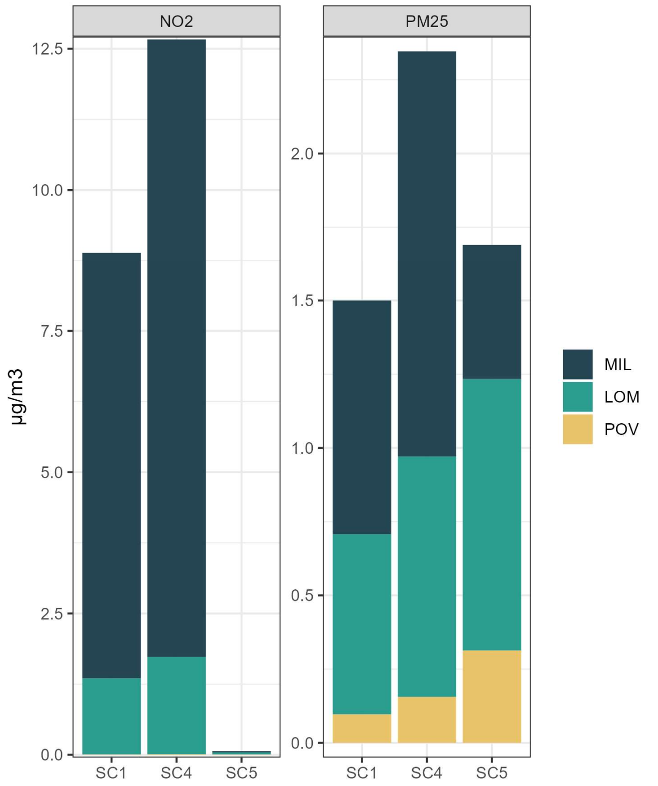
Code	Description
SC1	Moderate electrification of the light-duty vehicle fleet, at all spatial scales.
SC2	High electrification of the light-duty vehicle fleet, at local scale.
SC3	Reduction in travel demand. Heavy-duty vehicles: regional scale. Light-duty vehicles: local scale
SC4	Combination of measures from SC1 and SC3.
SC5	Reduction in biomass-based residential heating and agriculture sectors: all scales.

NO_2 PM2.5



BASECASE SCENARIOS BASECASE SCENARIOS

NO_2 PM2.5



Impact of different emission regions

Conclusion and next steps

Strong model performance: SIMBAD models show low bias and high correlation with CAMx in reproducing annual and daily PM2.5, PM10 and precursors concentrations across all scenarios.

Robust response to emission changes: The models reliably capture air-quality responses across sectors, spatial scales, and scenario complexity.

Policy support tool: SIMBAD models are well suited for multiscale air-quality planning, enabling assessment of coordinated emission-reduction strategies from national to urban levels.

Main Limitation: Absence of bias-correction procedures. The accuracy of SIMBAD scenarios depends on the performance of the reference CAMx simulations.

Next Steps: simulation of short-term air quality indicators, such as exceedances of concentration thresholds defined in the latest European air quality directive as well as health and economic impacts of scenarios for SIMBAD-RUM version over Milan/Lombardy domain

Development of SIMBAD-RUM version over Naples/Campania domain (end of 2027)

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