(*towards*) An integrated assessment model for efficient estimation of health costs reduction associated to air quality impact of emission control policies

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Our goal: efficient air quality integrated assessment modelling

- ❑ Lay the groundwork for a more explicit estimate of externalities due to air pollution

How accurately and quickly can health and environmental costs due to air pollution be quantified?

- ❑ Quantify environmental impact of planning tools outcomes

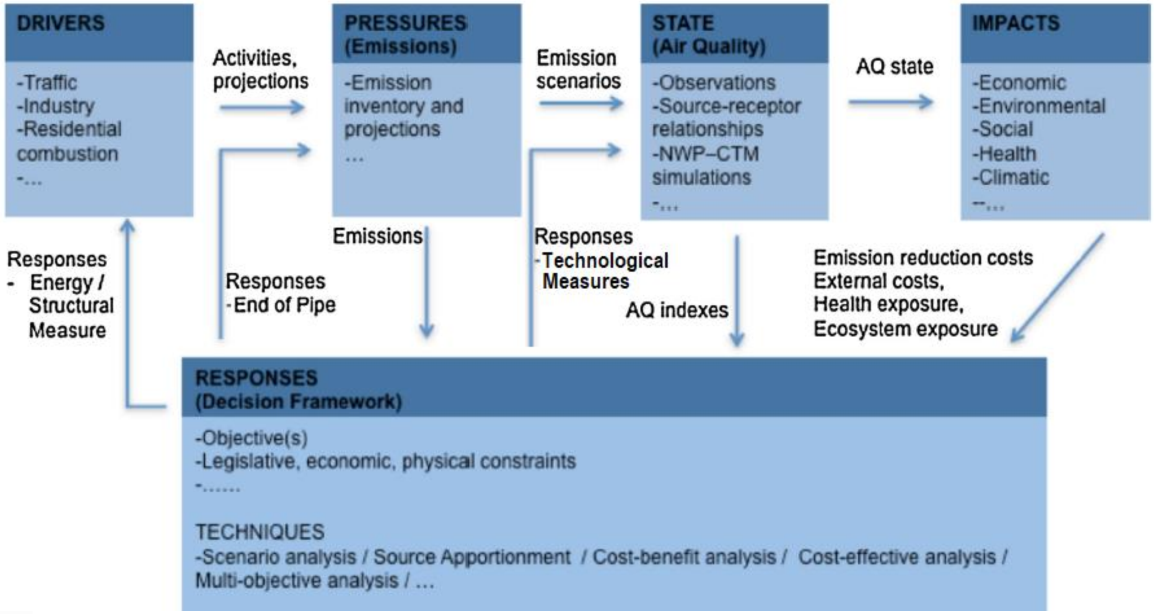
What is the air quality cost associated to a specific activity profile?

- ❑ Evaluate the potential of emission reduction scenarios

Which policies lead to the most favourable cost-benefit ratio?

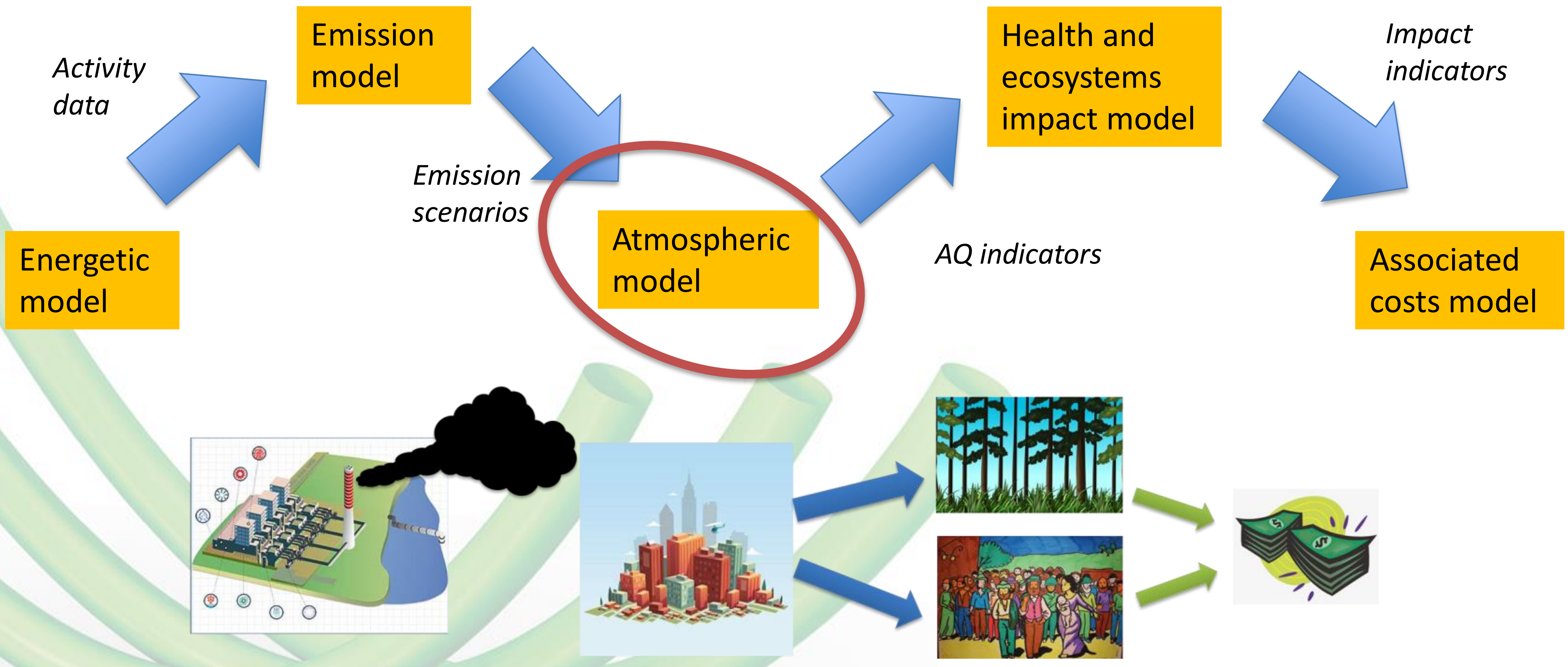
- ❑ Integrate energy and environmental models

Does an optimal energy scenario minimise air quality impact as well?



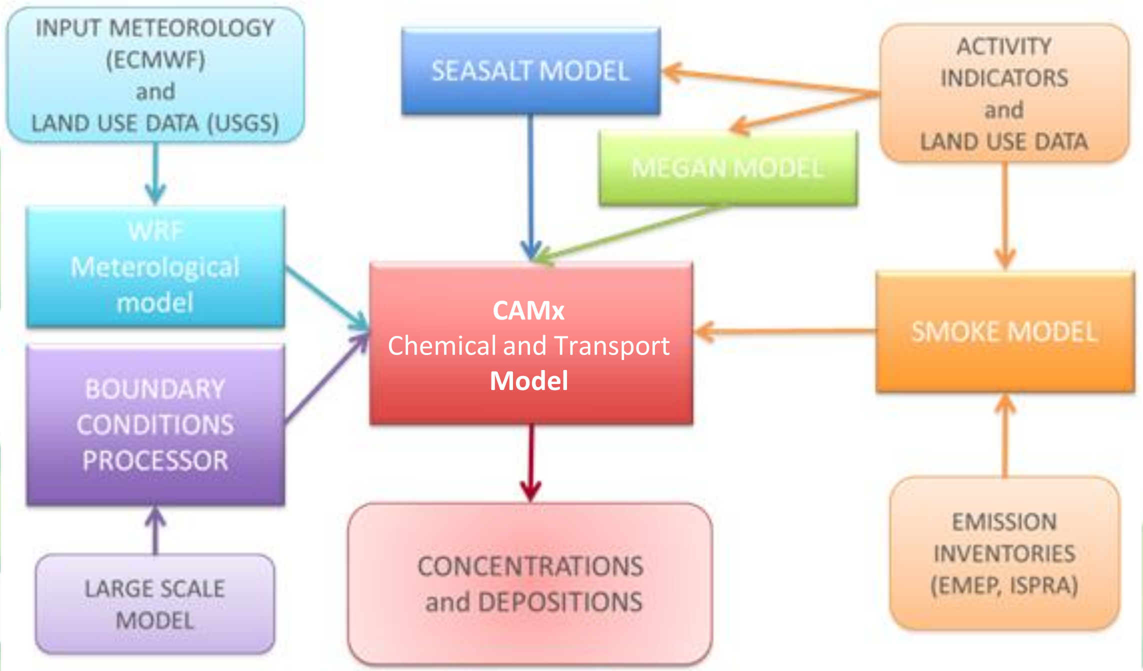
DPSIR scheme

Our tools: harmonised energetic-environmental modelling chain



Simplified emission-concentration model

To be practically useful, tools must be able to process a large number of scenarios in a short time



A «full optional» atmospheric modelling system may require several days for each scenario

No reinventing of the wheel

CAMx Decoupled Direct Method
(Dunker et al., 2002)

- ❑ Robust: formulation coherent with CAMx model
- ❑ Flexible: same setup as CAMx
- ❑ Adapts to multiple purposes
- ❑ Thoroughly tested

Simplified model based on CAMx-DDM

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Perturbation in generic input parameter

Perturbed input field, e.g. emissions of one or more pollutants/sources: $F(\underline{x},t) = f(\underline{x},t) + \lambda\, g(\underline{x},t)$ where

f = unperturbed input field, λ = amplitude, g = perturbation field

Taylor series representation of resulting concentration fields

$$c(\underline{x},t,\underline{\lambda}) = c(\underline{x},t,\underline{\lambda}_0) + \sum_{i=1}^{n} \left.\frac{\partial c}{\partial \lambda_i}\right|_{\underline{\lambda}_0} (\lambda_i - \lambda_{i,0}) + higher\ order\ terms$$

First order sensitivities: $s_i = \left.\frac{\partial c}{\partial \lambda_i}\right|_{\underline{\lambda}_0}$

Sensitivities calculation by CAMX-DDM

$$\left[\frac{\Delta C_p}{\Delta t}\right]_{i,j,k,l} = [\overline{\text{advection}} + \overline{\text{diffusion}} + \overline{\text{chemistry}} + \overline{\text{emissions}} + \overline{\text{deposition}}]_{i,j,k,l}$$

$$\left[\frac{\Delta S_p}{\Delta t}\right]_{i,j,k,l} = \left[\frac{\partial}{\partial\lambda}\overline{\text{advection}} + \frac{\partial}{\partial\lambda}\overline{\text{diffusion}} + \frac{\partial}{\partial\lambda}\overline{\text{chemistry}} + \frac{\partial}{\partial\lambda}\overline{\text{emissions}} + \frac{\partial}{\partial\lambda}\overline{\text{deposition}}\right]_{i,j,k,l}$$

Simplified relationship: $\underline{\lambda}_0 = 0$

$$c(\underline{x},t,\lambda_i) = c(\underline{x},t,0) + \lambda_i\, s_i(\underline{x},t)$$

Sensitivities s_i represent variations due to a perturbation with $\lambda_i = 1$, i.e. $g_i(\underline{x},t)$

$$c_{(scen)} = c_{(base)} + \sum_{i=1}^{n} \lambda_i s_{i\,(base)}^{(g_i)}$$

Simplified model formulation

Variation coefficient: $r_i = \frac{Emix(scenario)}{Emix(base)}\%$ for each pollutant and/or source set i $\qquad \lambda_i = \frac{100 - r_i}{50}$

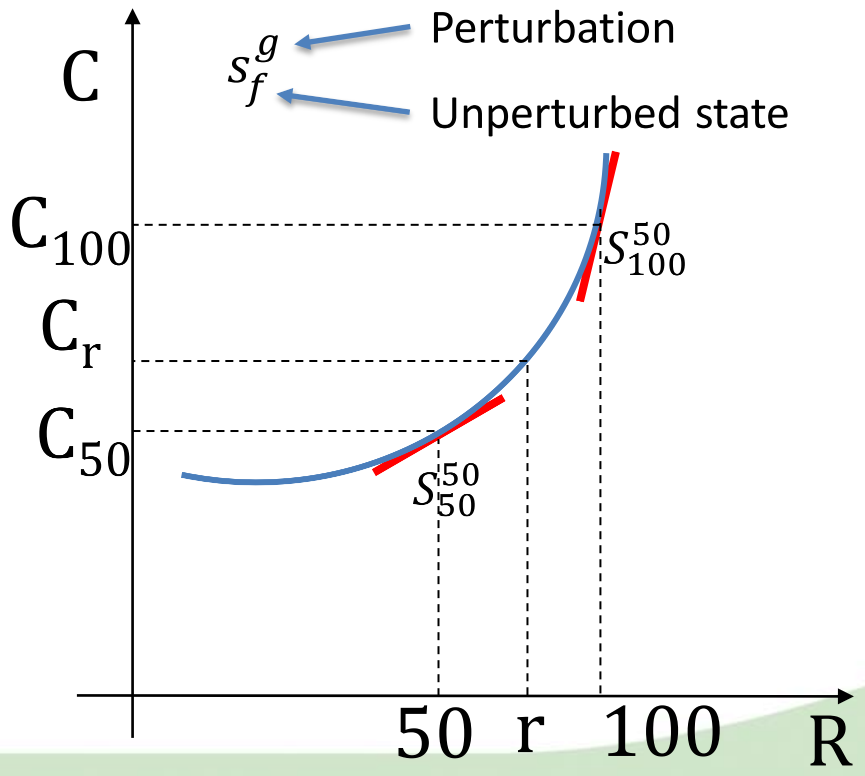
$$c_{(\bar{r})} = \sum_{i=1}^{N}\left(\omega_{i(100)}\left(\frac{c_{(100)}}{N} - \lambda_i s_{i(100)}^{(50)}\right) + \omega_{i(50)}\left(\frac{c_{(50)}}{N} + (1-\lambda_i)s_{i(50)}^{(50)}\right)\right) \qquad 50\% \leq ri \leq 100\%$$

$$\omega_{i(100)} = \frac{r_i - 50}{50}\ ; \qquad \omega_{i(50)} = \frac{100 - r_i}{50}$$

$$c_{(\bar{r})} = c_{(100)} - \sum_{i=1}^{N}\lambda_i s_{i(100)}^{(50)} \qquad r_i > 100\%$$

$$c_{(\bar{r})} = c_{(50)} + \sum_{i=1}^{N}(1-\lambda_i)s_{i(50)}^{(50)} \qquad 0 < ri < 50\%$$

Applied and tested with NO_2, PM2.5, PM10, primary PM.
For ozone, using first order sensitivities is not enough



Our tools: harmonised energetic-environmental modelling chain

Energetic model

Activity data

Emission model

Emission scenarios

Atmospheric model

AQ indicators

Health and ecosystems impact model

Impact indicators

Associated costs model

Health costs modelling

HRAPIE project methodology

Log-linear impact function, dependent on long term concentration delta (e.g. annual mean):

$$HI_{ijk} = P_{ij} \cdot r_{ijk}\left(1 - \frac{1}{e^{\beta_k \Delta \bar{C}_{ij}}}\right)$$

Considered pollutants: NO_2 and PM10

Implemented indicators: avoided deaths, avoided YOLL (Years Of Life Lost)

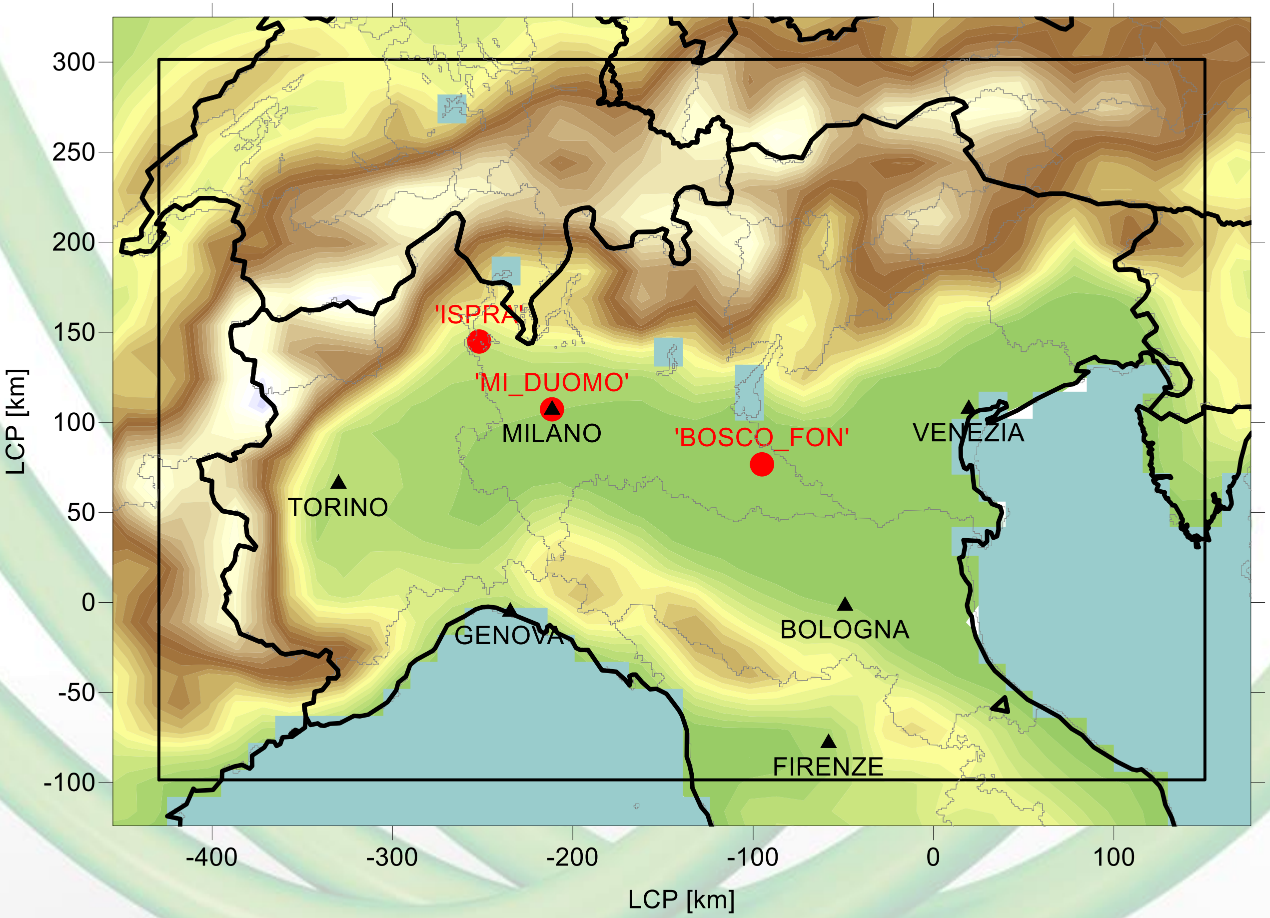
Cost estimation based on Value of Statistical Life (VSL):

$$VSL = \frac{\mathrm{WTP}(\delta \mathrm{r})}{\delta \mathrm{r}}$$

i.e. Willingness To Pay for an increment of relative risk

$$Cost = VSL \times YOLL$$

Simplified emission-concentration model: test case



Simulation	Base emission fields	Perturbation (emission reduction)
00BASE_MS50	2010 emissions	50 % industry, transport, agriculture
SCEN14_MS50	2010 emissions with a 50% reduction on industry, transport, agriculture	50 % industry, transport, agriculture

Simplified emission-concentration model: test case

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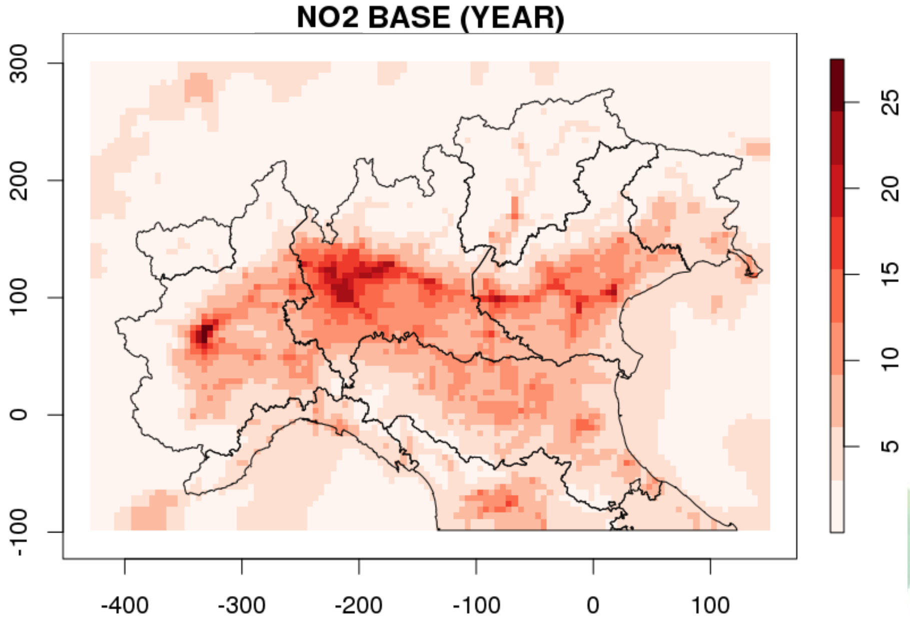
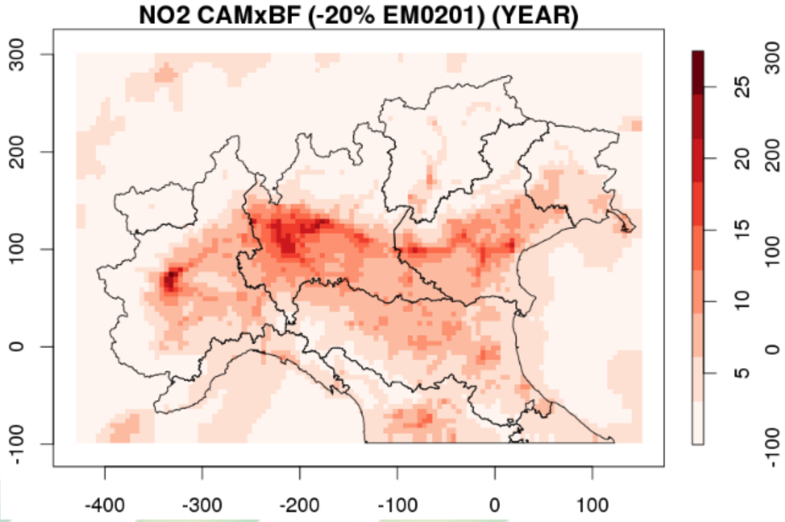
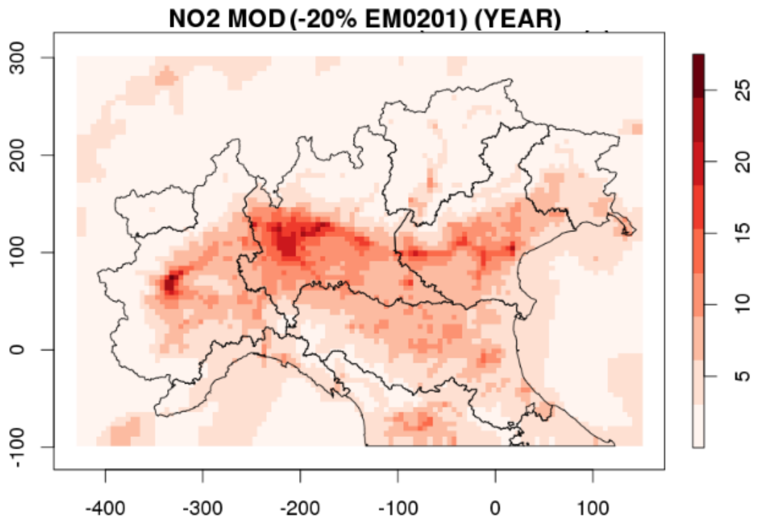
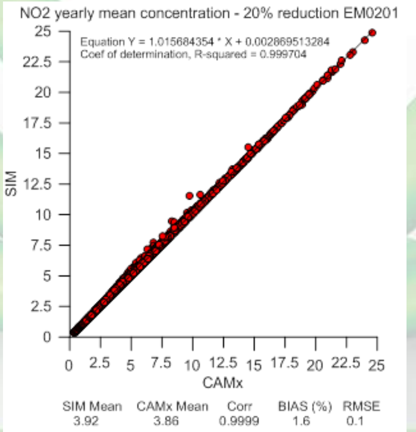
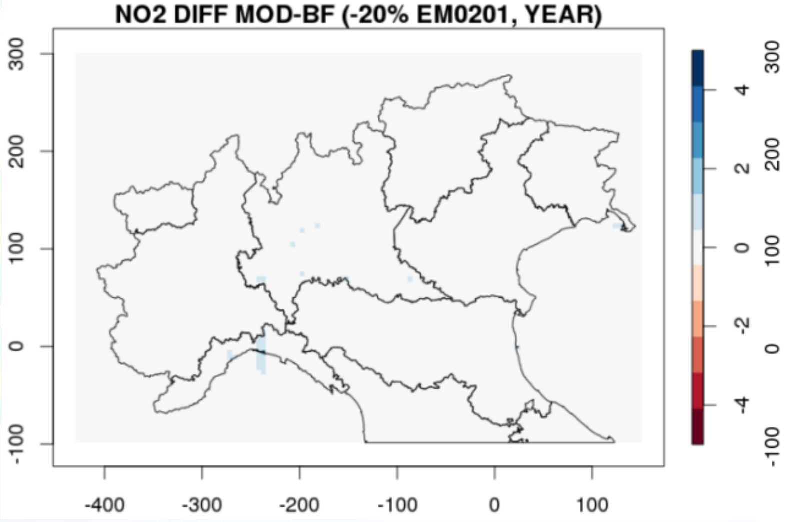
NO_2 – Average annual concentration – 20% Reduction on road traffic emissions

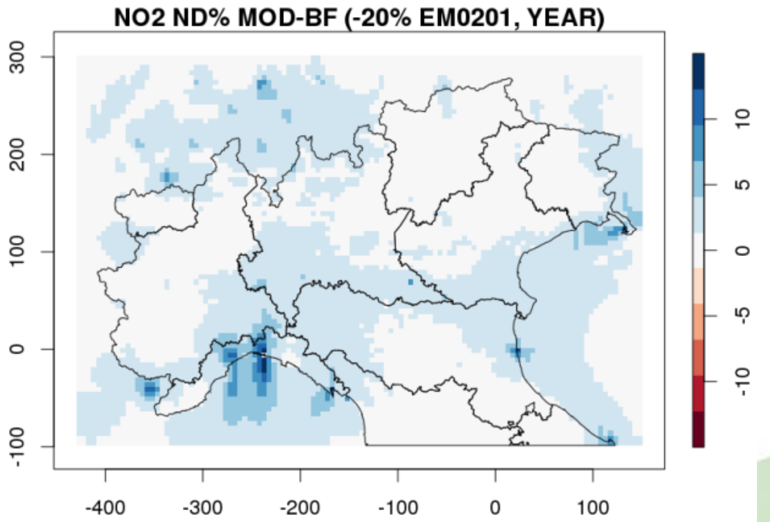






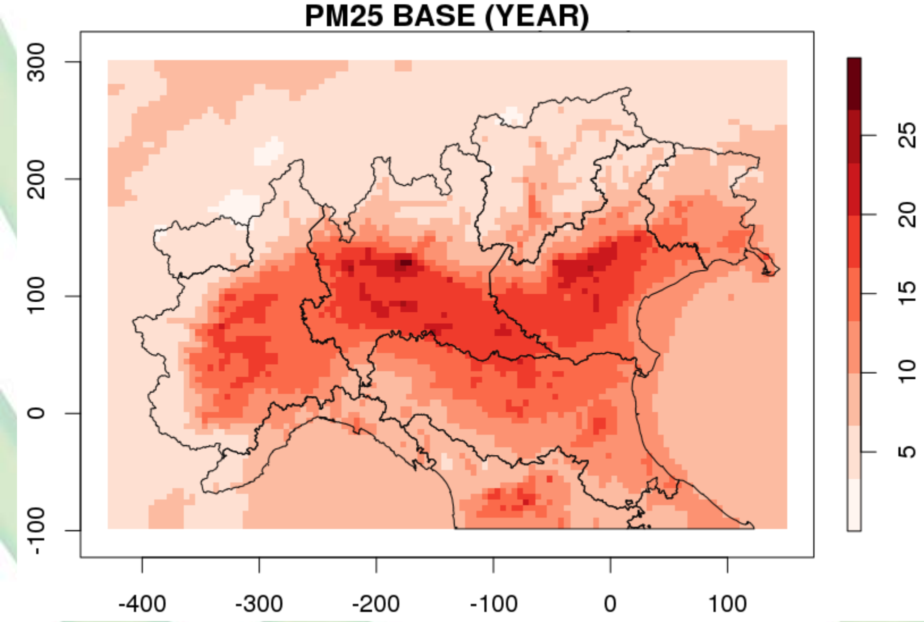


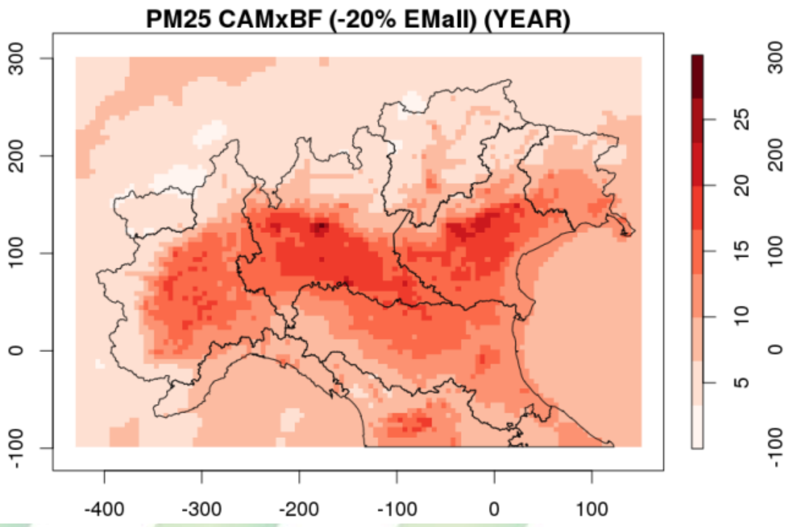


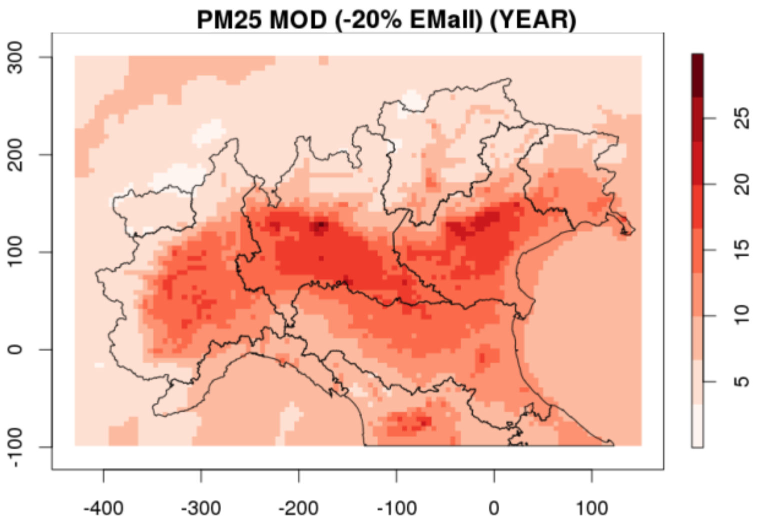


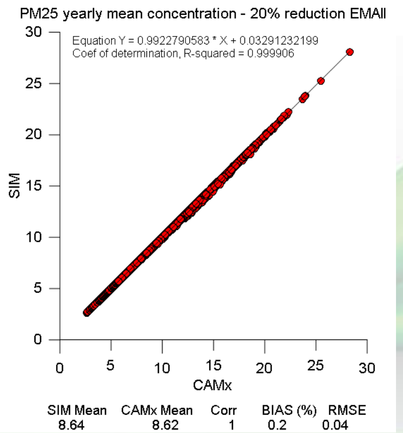
Simplified emission-concentration model: test case

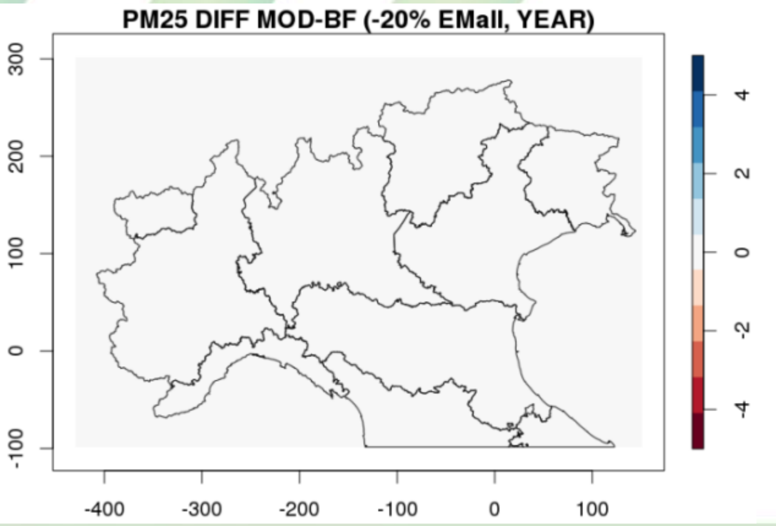
PM2.5 – Average annual concentration – 20% Reduction on road traffic, industry and agriculture emissions

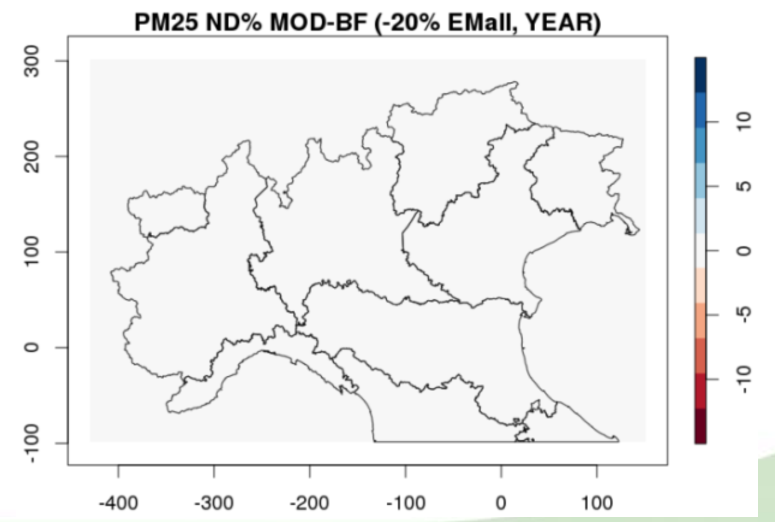






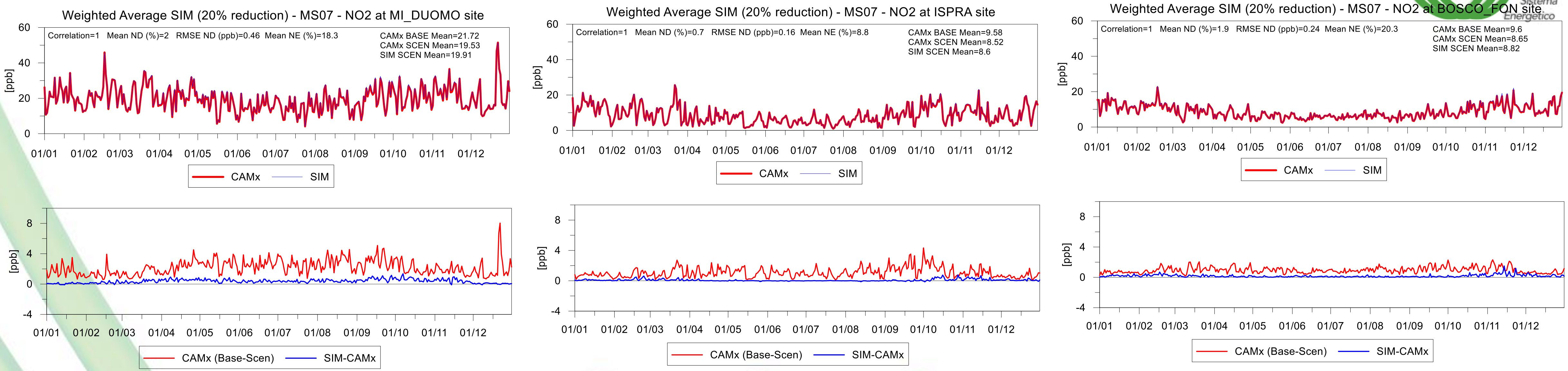




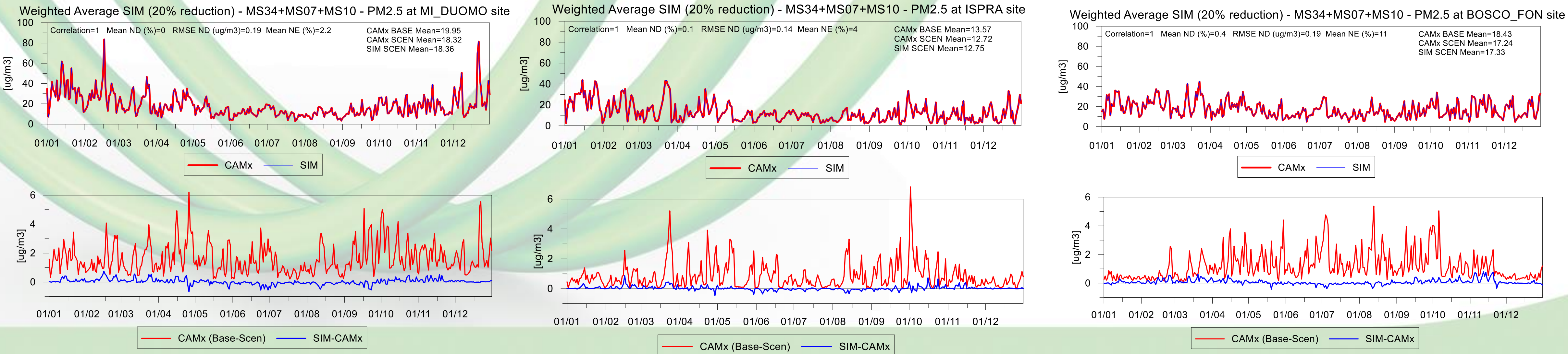


Simplified emission-concentration model: test case

NO_2 – Average daily concentration – 20% Reduction on road traffic emissions



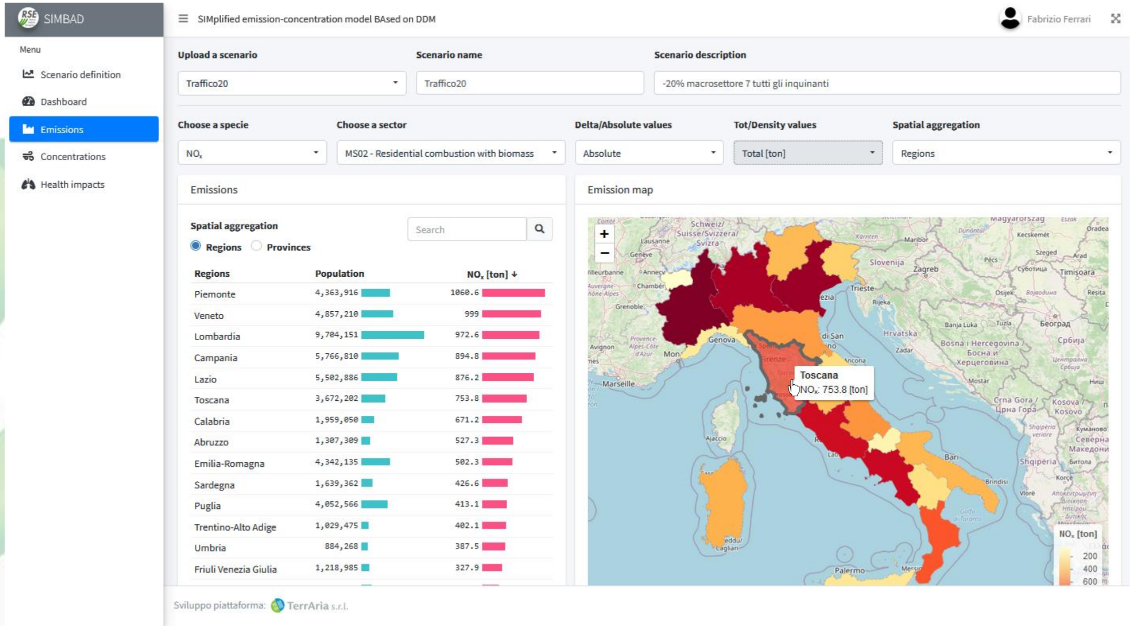
PM2.5 – Average daily concentration – 20% Reduction on road traffic, industry and agriculture emissions



Simplified emission-concentration model: national scale

Simulation	Base emission fields	Perturbations (emission reductions)
BASE_02R07T_P50	2015 emissions	*50% for* *- heating with biomass* *- heating with other fuels* *- road transport*
SCE50_02R07T_02R07T_P50	2015 emissions with a 50% reduction on - non-industrial combustion - road transport	*50% for* *- heating with biomass* *- heating with other fuels* *- road transport*
BASE_DDM_01E_P100	2015 emissions	*100% for* *public power plants*

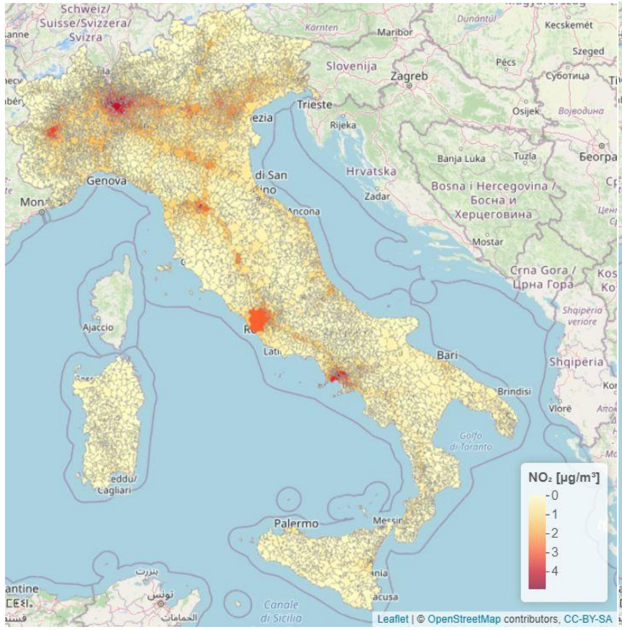
User-friendly web application



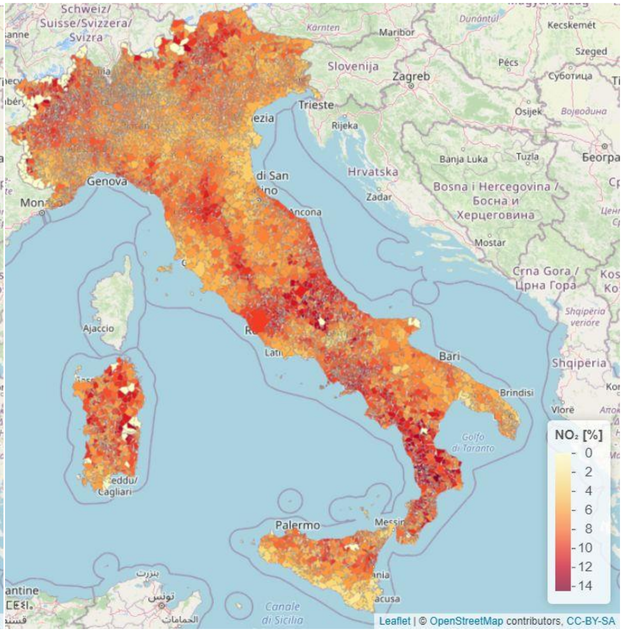
Application examples

Scenario where biomass for heating is replaced by natural gas

NO_2 variations by municipality

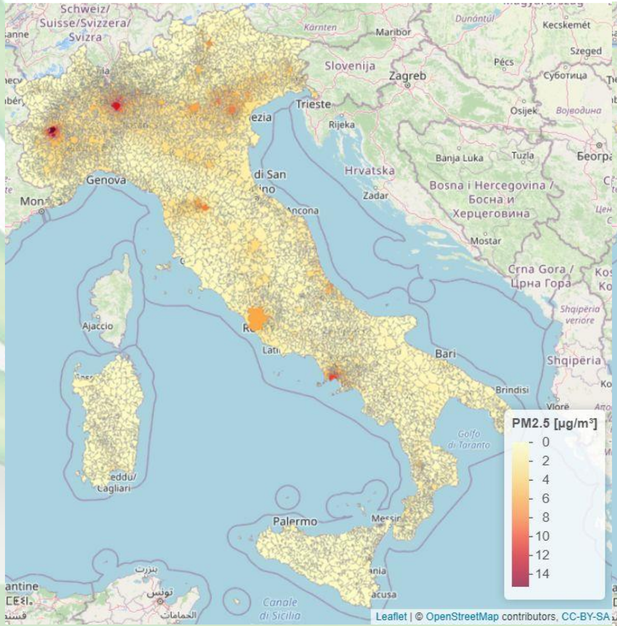


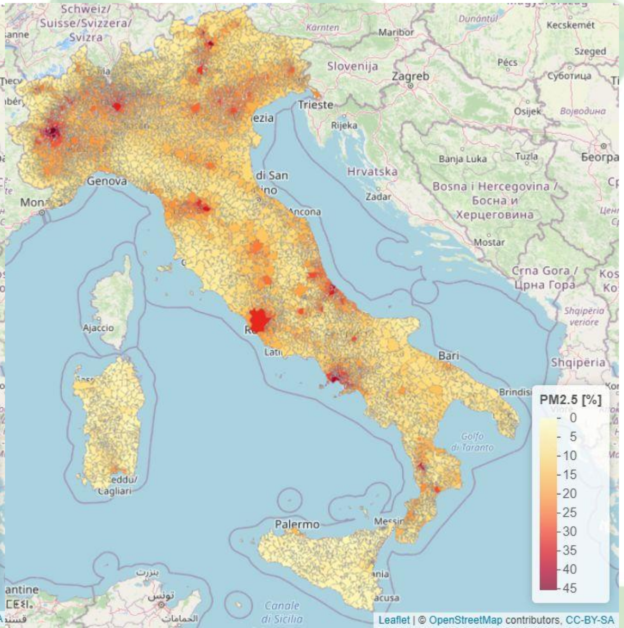
Absolute (µg/m³)

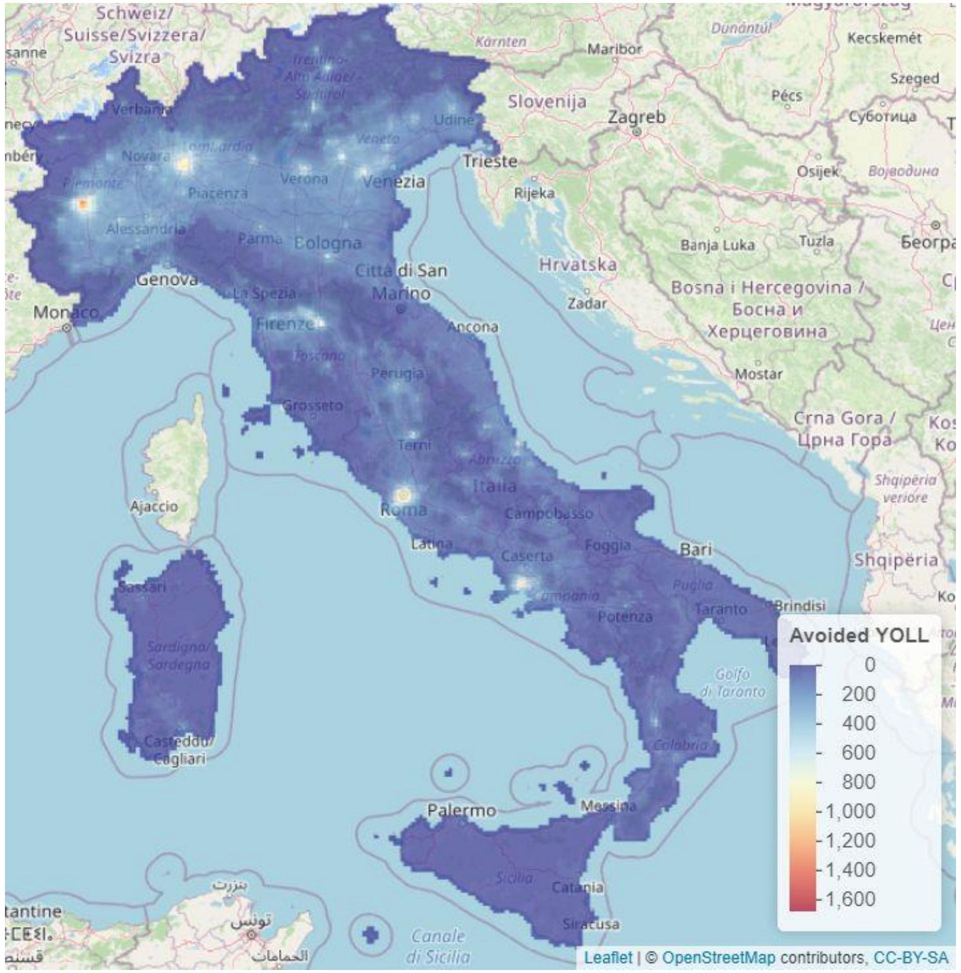


Relative (%)

PM10 variations by municipality





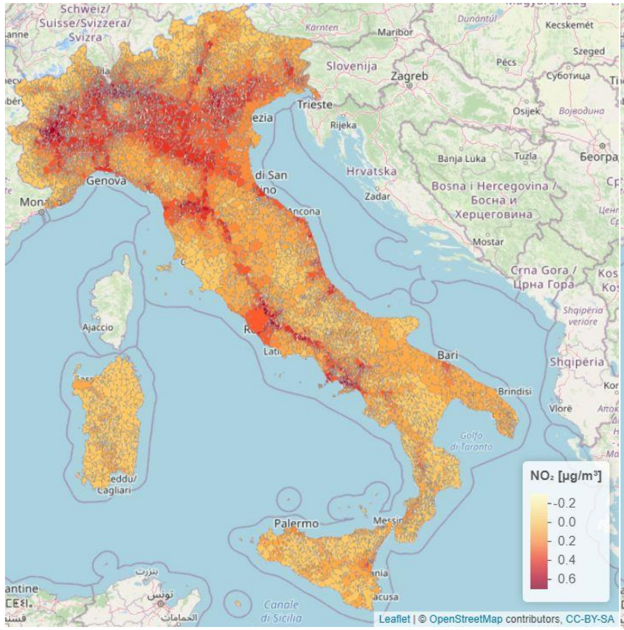


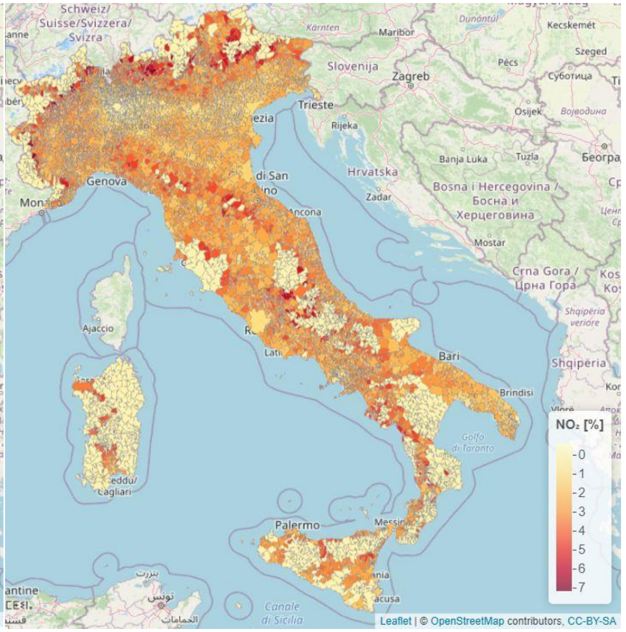
Avoided YOLL per 100.000 inhabitants

Application examples

Scenario with 30% reduction of diesel vehicles

NO_2 variations by municipality





Absolute (µg/m³) Relative (%)

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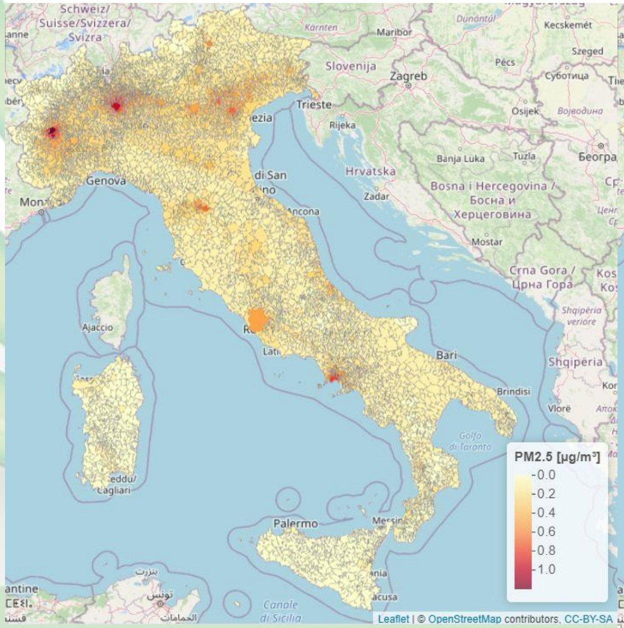

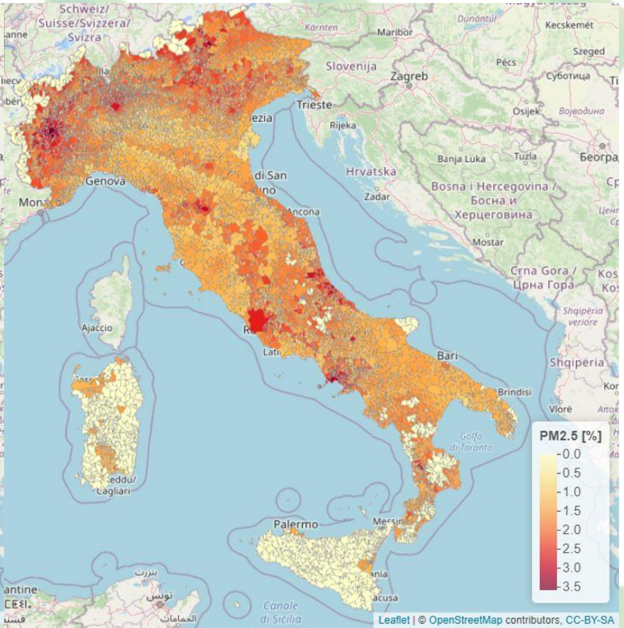

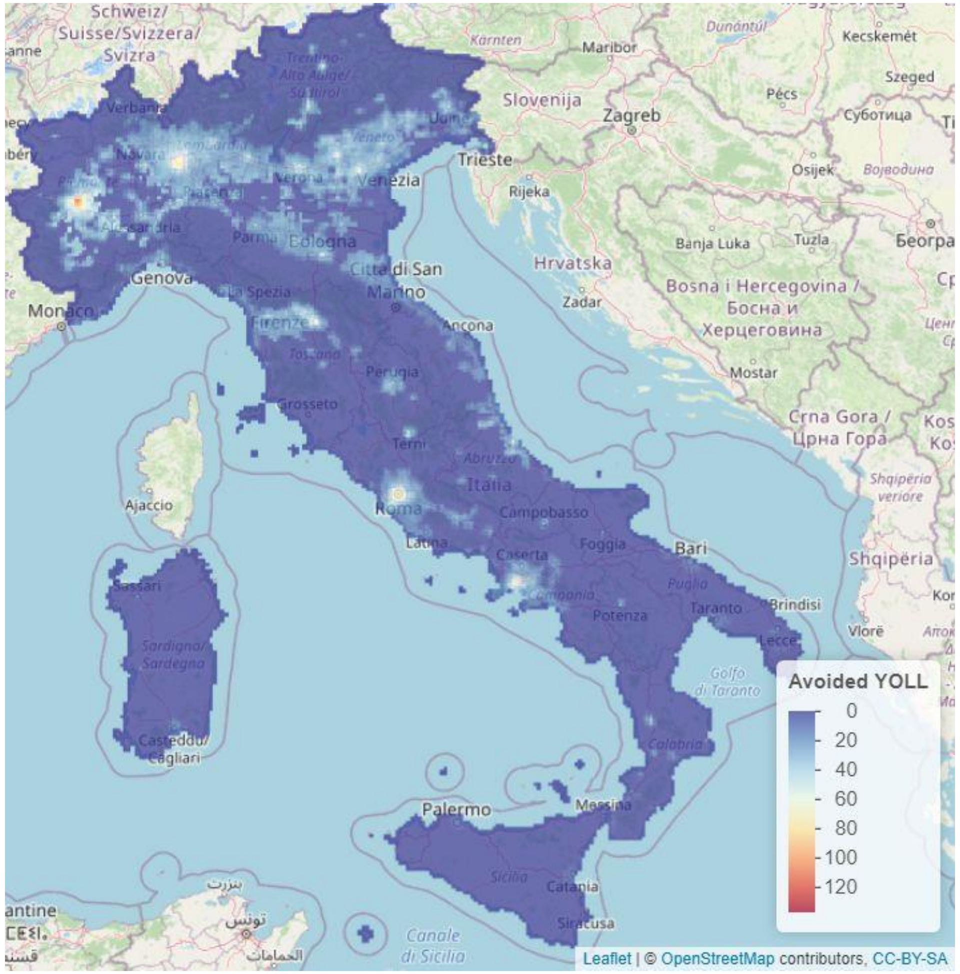

Avoided YOLL per 100.000 inhabitants

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Thank you for your attention

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