FAIRMODE WG4 – Planning
Proposed methodology

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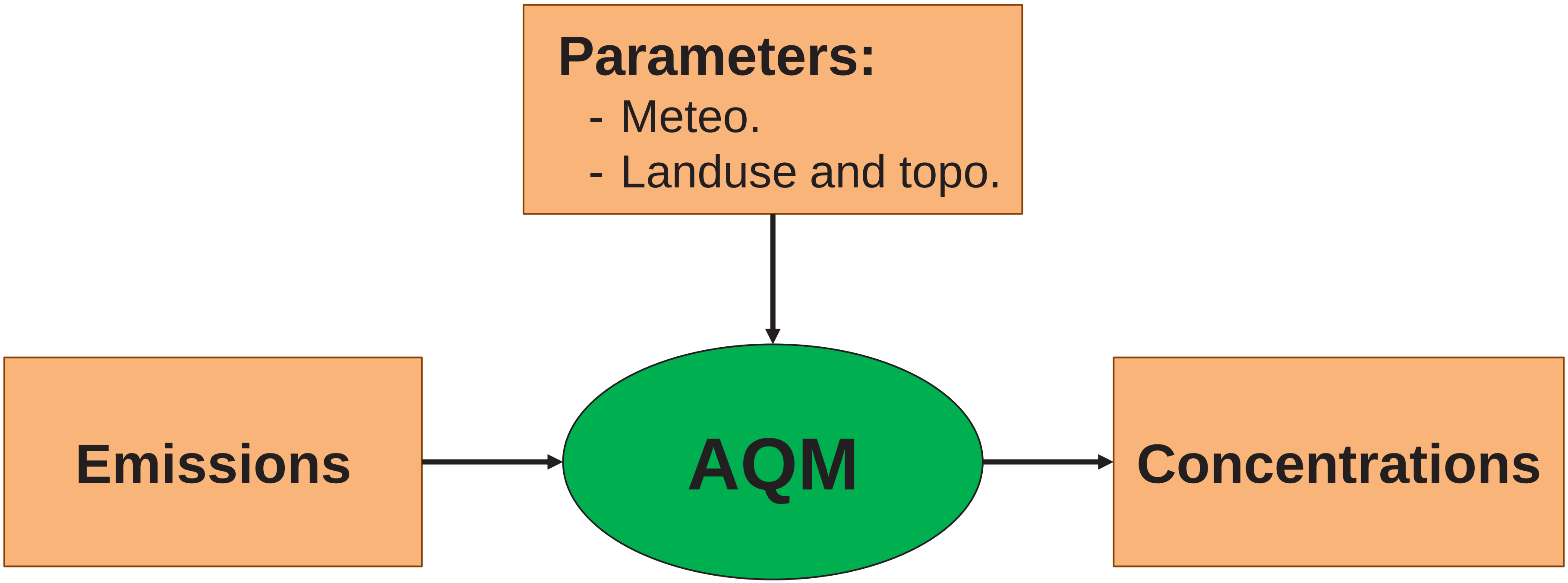
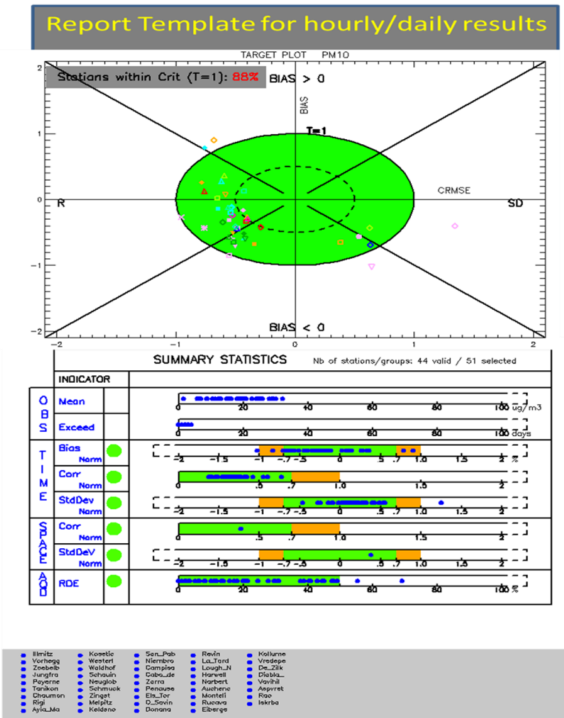
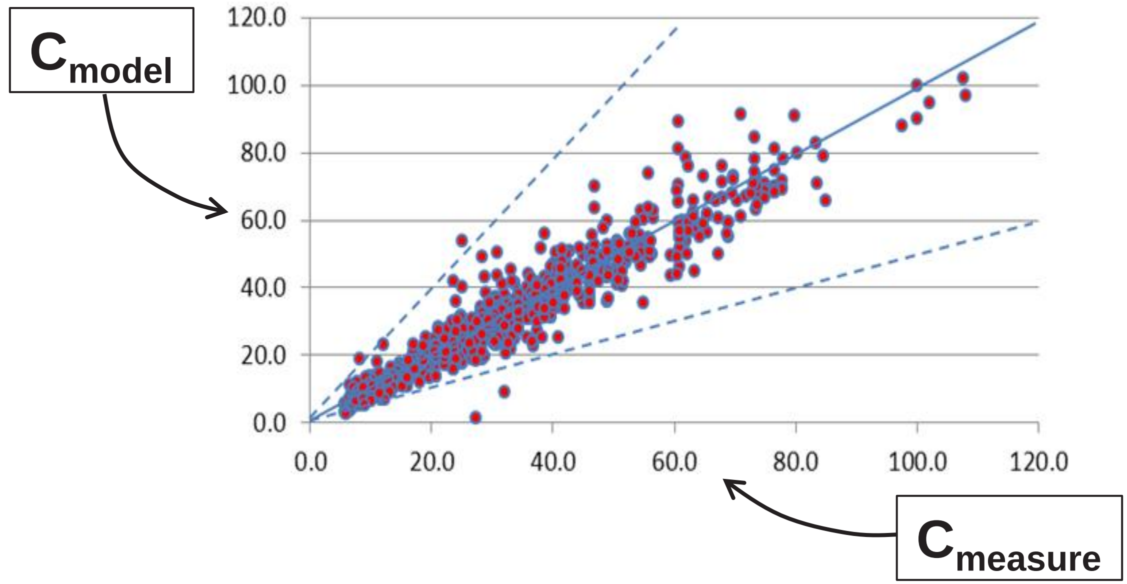
Air Quality Models



MODEL VALIDATION

WG 1: Assessment





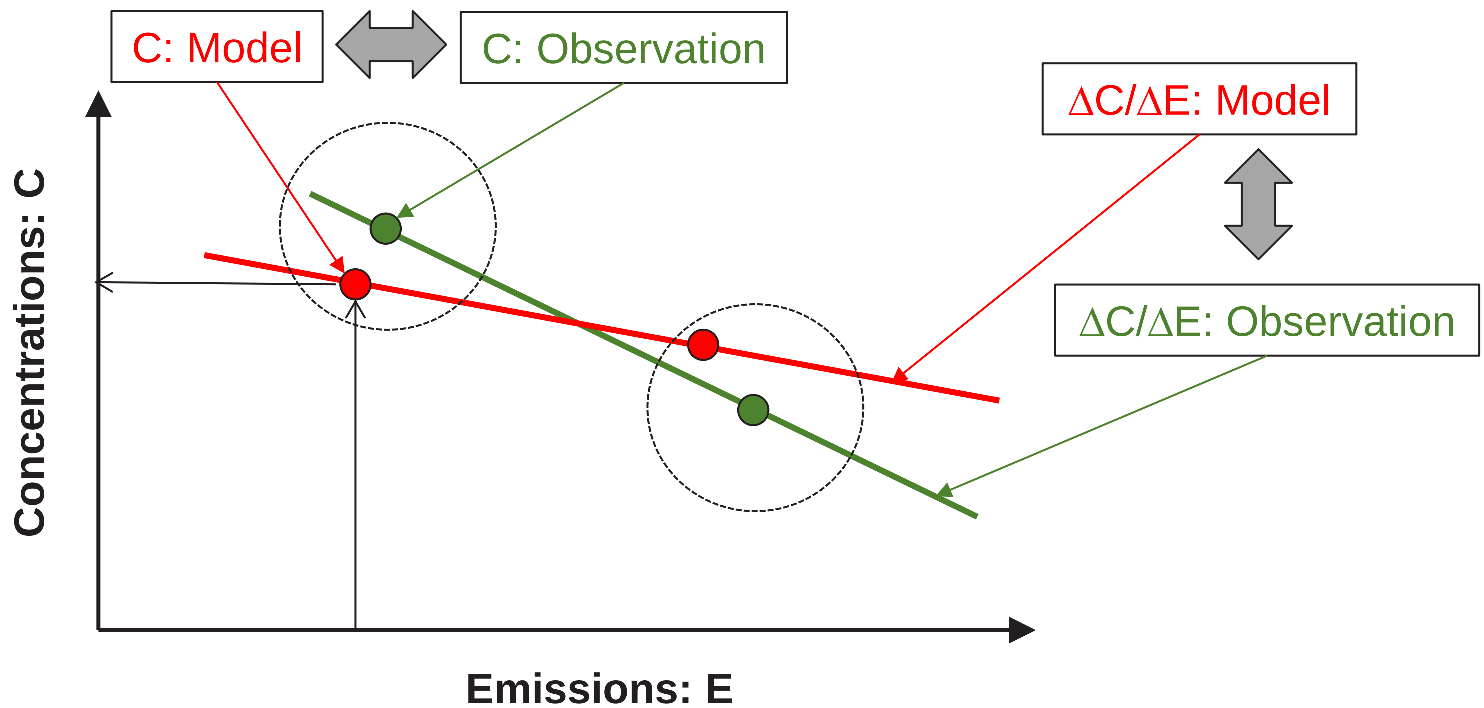
Validation based on comparisons of observed and modelled concentrations:

⇨ fine to forecast the concentration exceeding the limit values

⇨ but is it adapted for air quality planning?

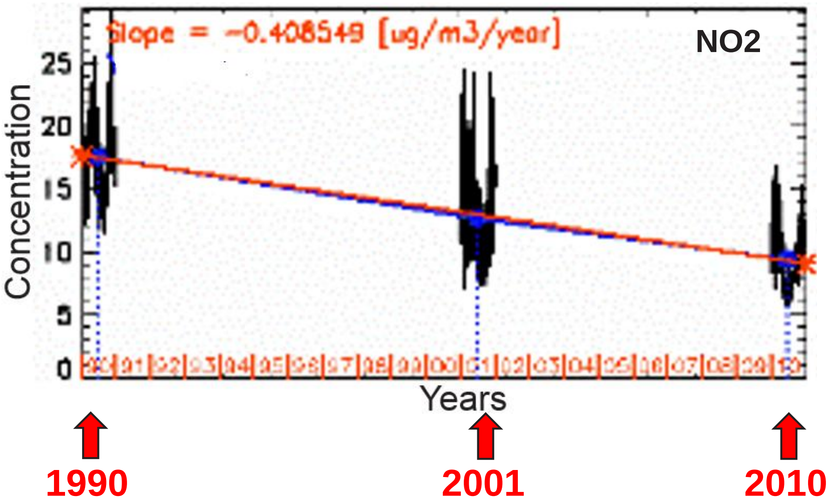
MODEL VALIDATION

WG 4: Planning

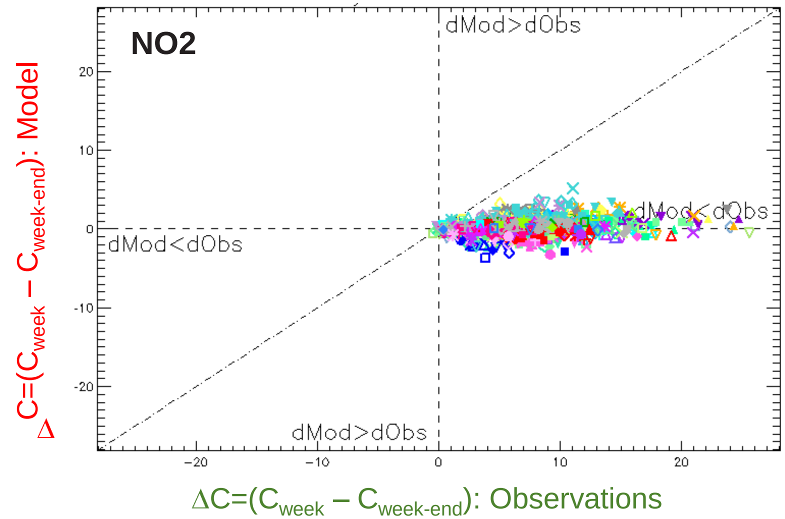


METHODOLOGIES

Trend analysis



Segregation periods



$\Delta C/\Delta t$: Model ⟷ $\Delta C/\Delta t$: Observation

ΔC Model ⟷ ΔC Observation

$\Delta C/\Delta E$: Model ⟷? $\Delta C/\Delta E$: Observation

ΔE: Model ⟷? ΔE: Real →

WG 2: Source apportionment

WG 3: Emissions

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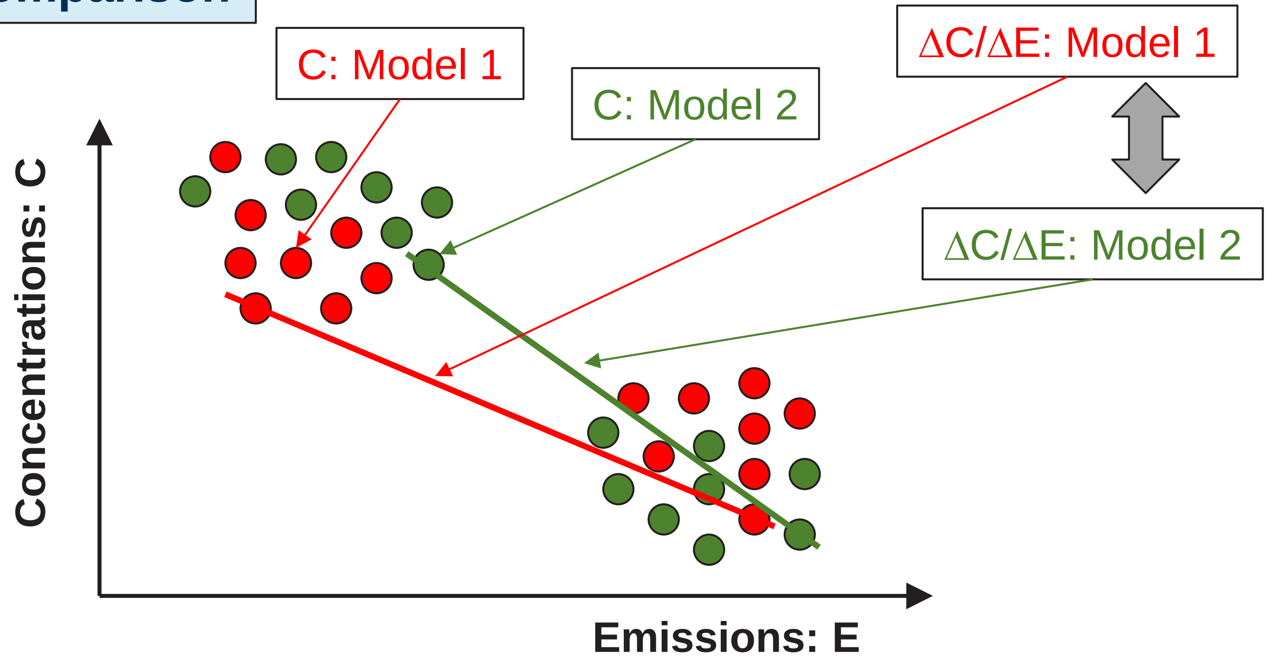
METHODOLOGIES

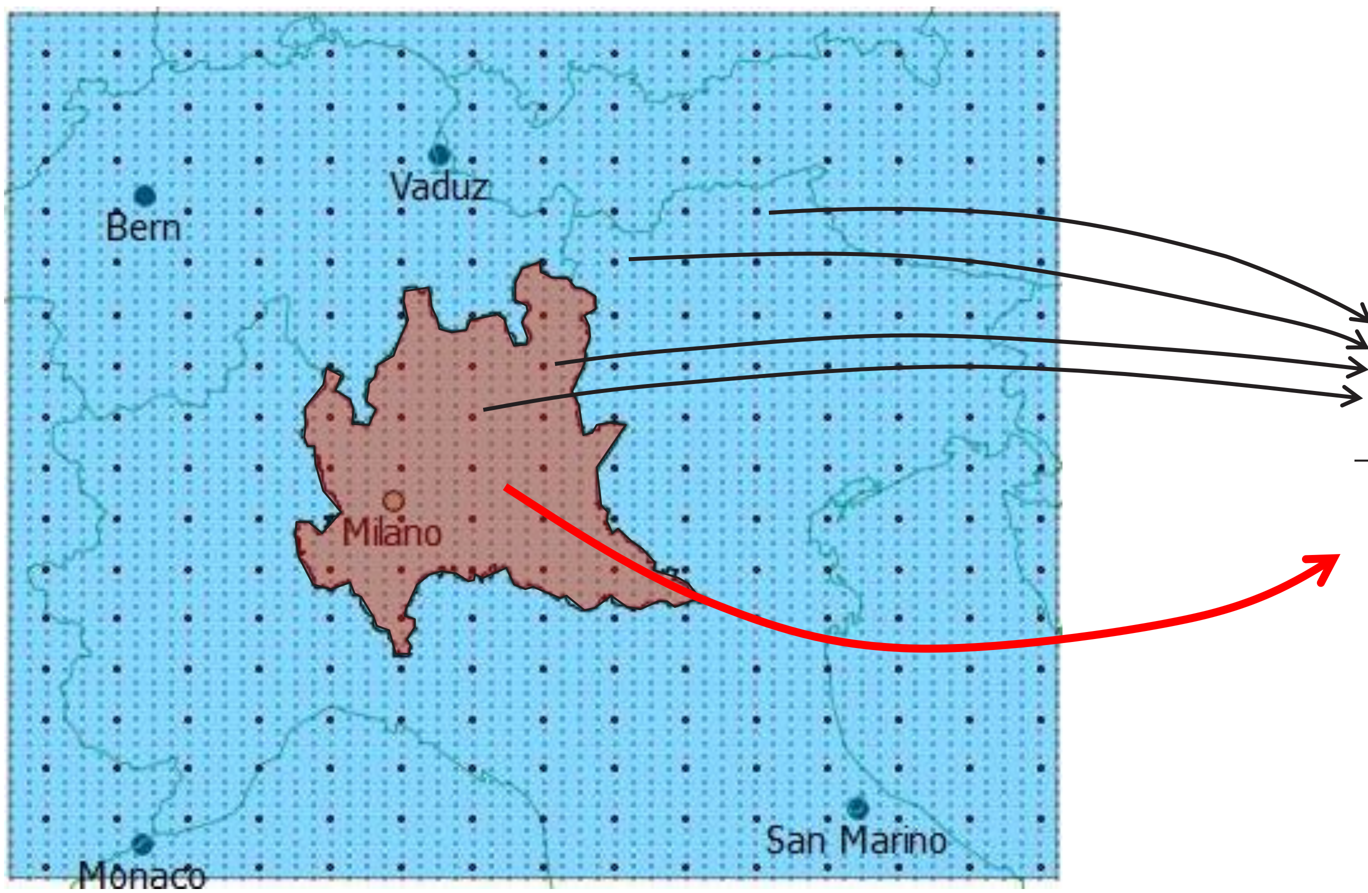
Model inter-comparison



The idea is to find indicators based on the ratio ΔC/ΔE.
This ratio is, in fact, complex because it depends from several model input parameters.

ΔC/ΔE RATIOS

The ratio ΔC/ΔE is relative to a reduction area:

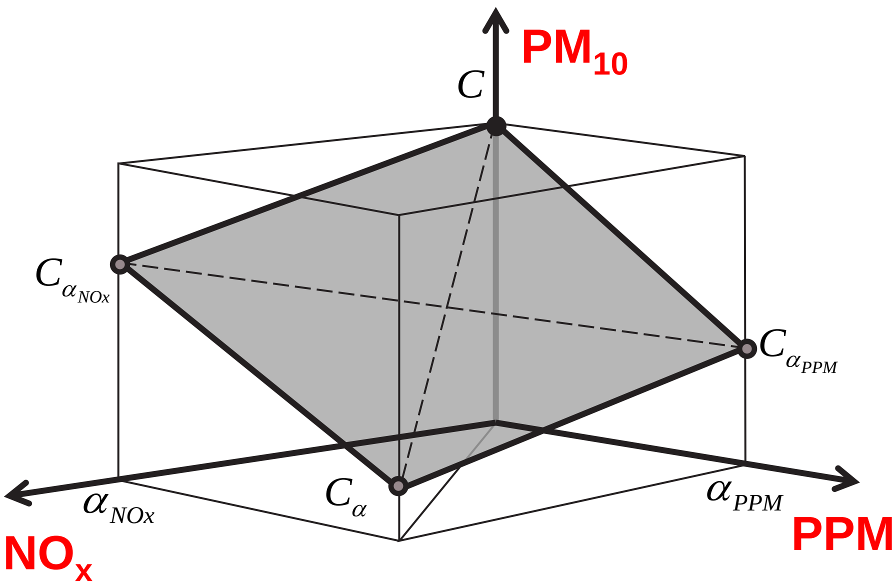


$$\frac{\Delta C_{x,y}}{\Delta E_{Milano}}$$

ΔC/ΔE RATIOS

The ratio ΔC/ΔE is relative to different precursors

The emissions of a series of precursors like NO_x, PPM, VOC, SO_2, NH_3, gives pollutant concentrations like PM or O_3.



C : Pollutant concentration (O_3) without any emission reduction

α_{NOx} is the relative emission change of a first precursor (NO_x)

$$\alpha_{NOx} = \Delta E_{NOx} / E_{NOx}$$

α_{PPM} same but for a second precursor (PPM)

$C_{\alpha_{NOx}}$: Pollutant concentration after reduction of the first precursor only

$C_{\alpha_{PPM}}$: same but after reduction of the second precursor only

C_α : Pollutant concentration after reduction of all precursors

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INDICATORS

Absolute potencies

*For **several precursors**:*

$$P_\alpha = \frac{\Delta C_\alpha}{\Delta E}$$

Pollutant concentration change over the emission change of all the precursors (PPM, NO_x , SO_2 , NH_3 , and VOC).

α the relative change of the total emission: $\alpha = \Delta E / E$ $\quad E = \sum_k E_k$

*For a **single precursor**:*

$$P_{\alpha_{NOx}} = \frac{\Delta C_{\alpha_{NOx}}}{\Delta E_{NOx}}$$

Pollutant concentration change over the emission change of NO_x only.

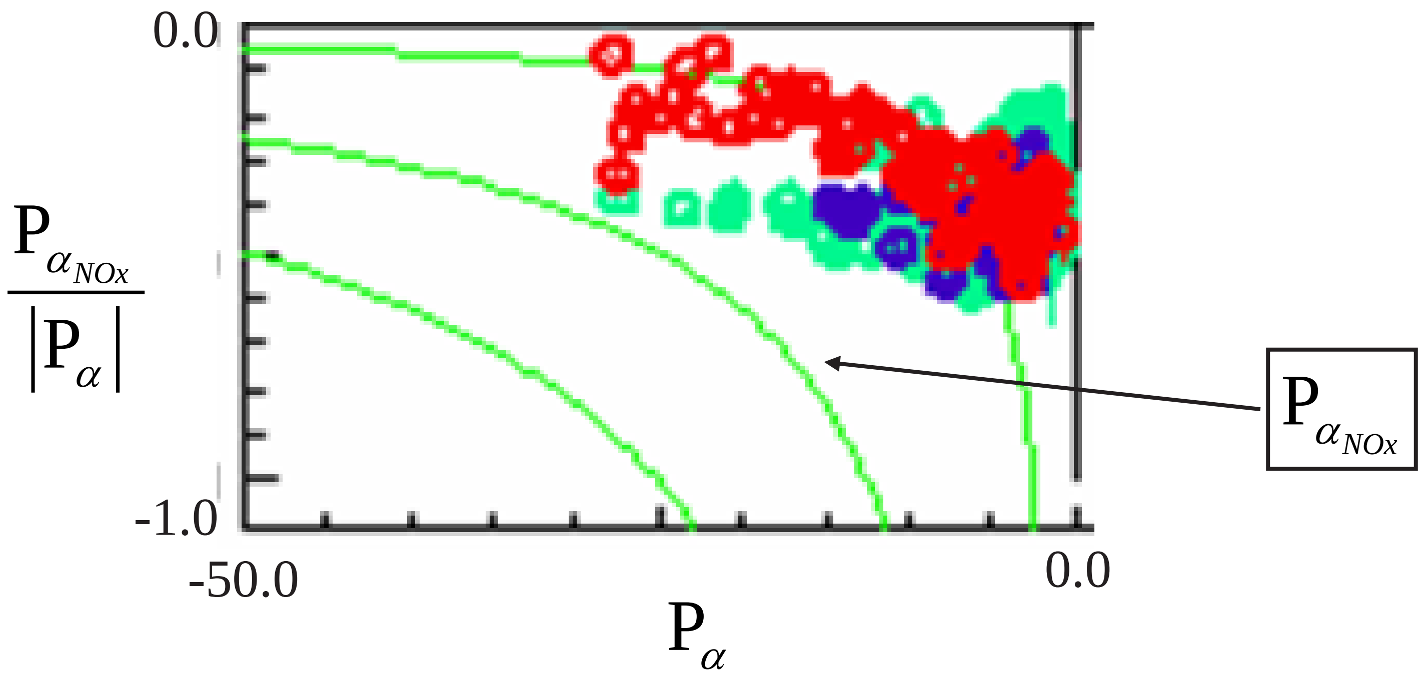
α_{NOx} is the relative emission change of the precursor: $\alpha_{NOx} = \Delta E_{NOx} / E_{NOx}$

INDICATORS

Single vs. several precursors contributions

$$P_\alpha = \frac{\Delta C_\alpha}{\Delta E}$$

Impact of NO_x reduction on PM10 over Po Valley



INDICATORS

Relative potencies

$$\Delta C_\alpha \Rightarrow \Delta C_\alpha / C \quad \text{and} \quad \Delta E \Rightarrow \Delta E / E = \alpha$$

*For **several precursors**:*

$$p_\alpha = \frac{\Delta C_\alpha / C}{\Delta E / E} = \frac{\Delta C_\alpha / C}{\alpha}$$

Relative concentration change over the relative emission change of all the precursor (NO_x , PPM, VOC, …).

*For a **single precursor**:*

$$p_{\alpha_{NOx}} = \frac{\Delta C_{\alpha_{NOx}} / C}{\alpha_{NOx}}$$

Relative concentration change over the relative emission change of NO_x only.

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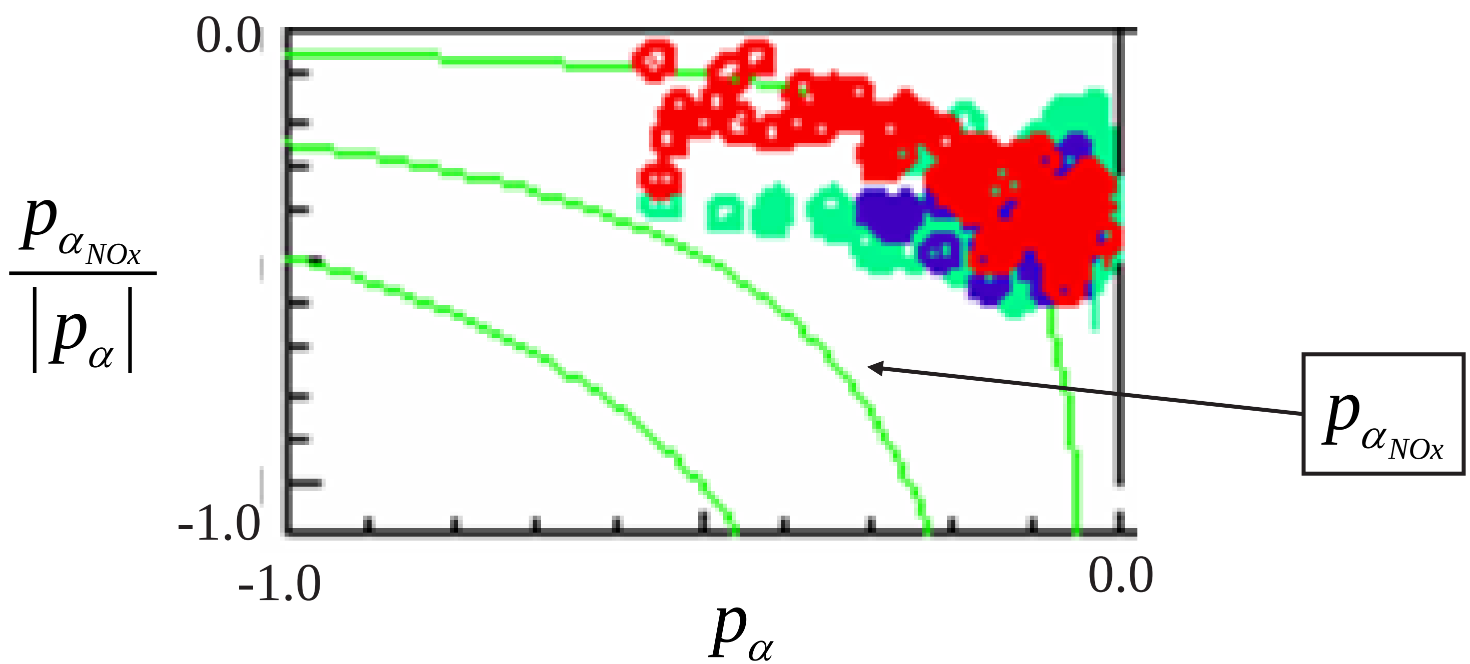
INDICATORS

"Bounded" indicators

$$p_\alpha = \frac{\Delta C_\alpha / C}{\alpha}$$

Relative impact of NO_x reduction on PM10 over Po Valley



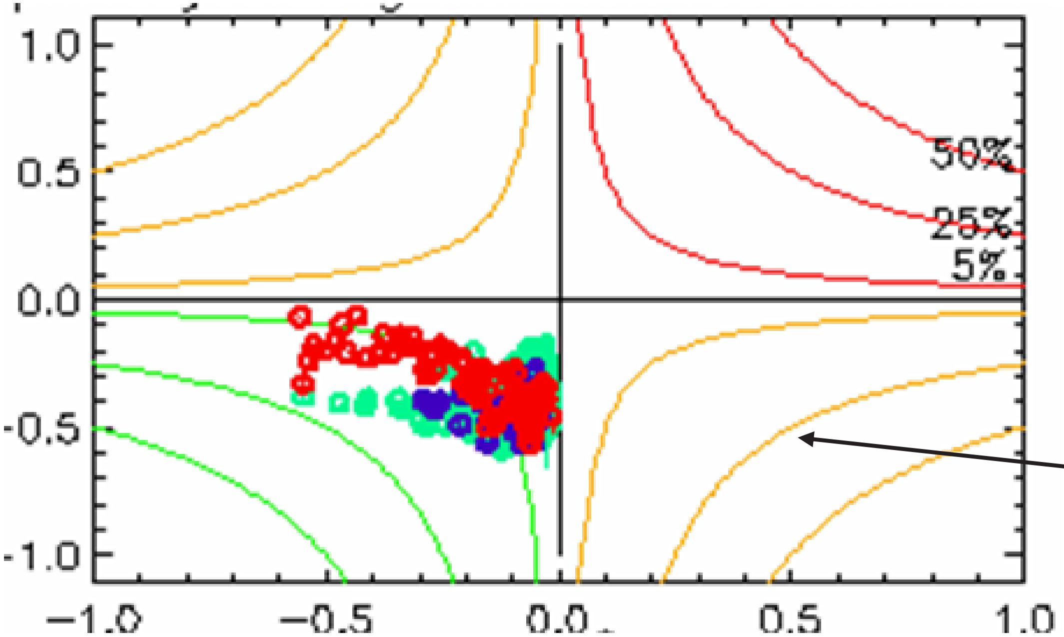
INDICATORS

Negative and positive contributions

$$p_\alpha = \frac{\Delta C_\alpha / C}{\alpha}$$

Relative impact of NO_x reduction on PM10 over Po Valley

$$\frac{p_{\alpha_{NOx}}}{|p_\alpha|}$$



p_α

$p_{\alpha_{NOx}}$

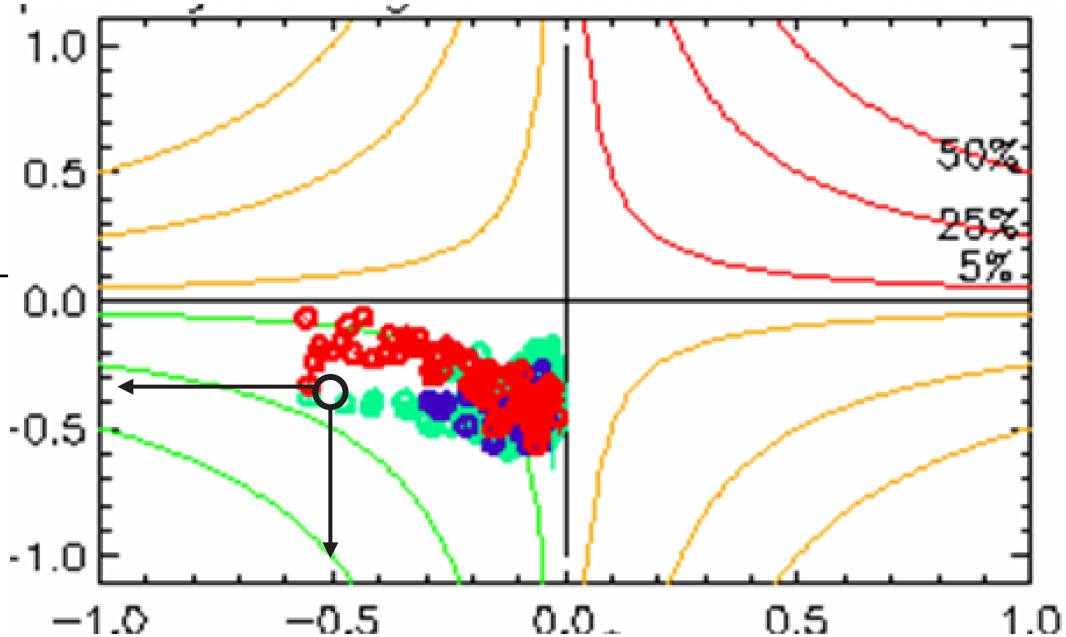
INDICATORS

Maximum potency

$$p_{\alpha} = \frac{\Delta C_{\alpha} / C}{\alpha}$$

Relative impact of NO_x reduction on PM10 over Po Valley

$$J = \frac{p_{\alpha_{NOx}}}{\left| I_{max} \right|}$$



$$I_{max} = \max\left[p_{\alpha} ; p_{\alpha_{NOx}} ; p_{\alpha_{PPM}} ; \ldots \right]$$

$$I_{max} = 0.5$$

$$\Delta C_{\alpha} / C = 0.5 \times \alpha$$

$$\Delta C_{\alpha} / C = 0.5 \times 20\% = 10\%$$

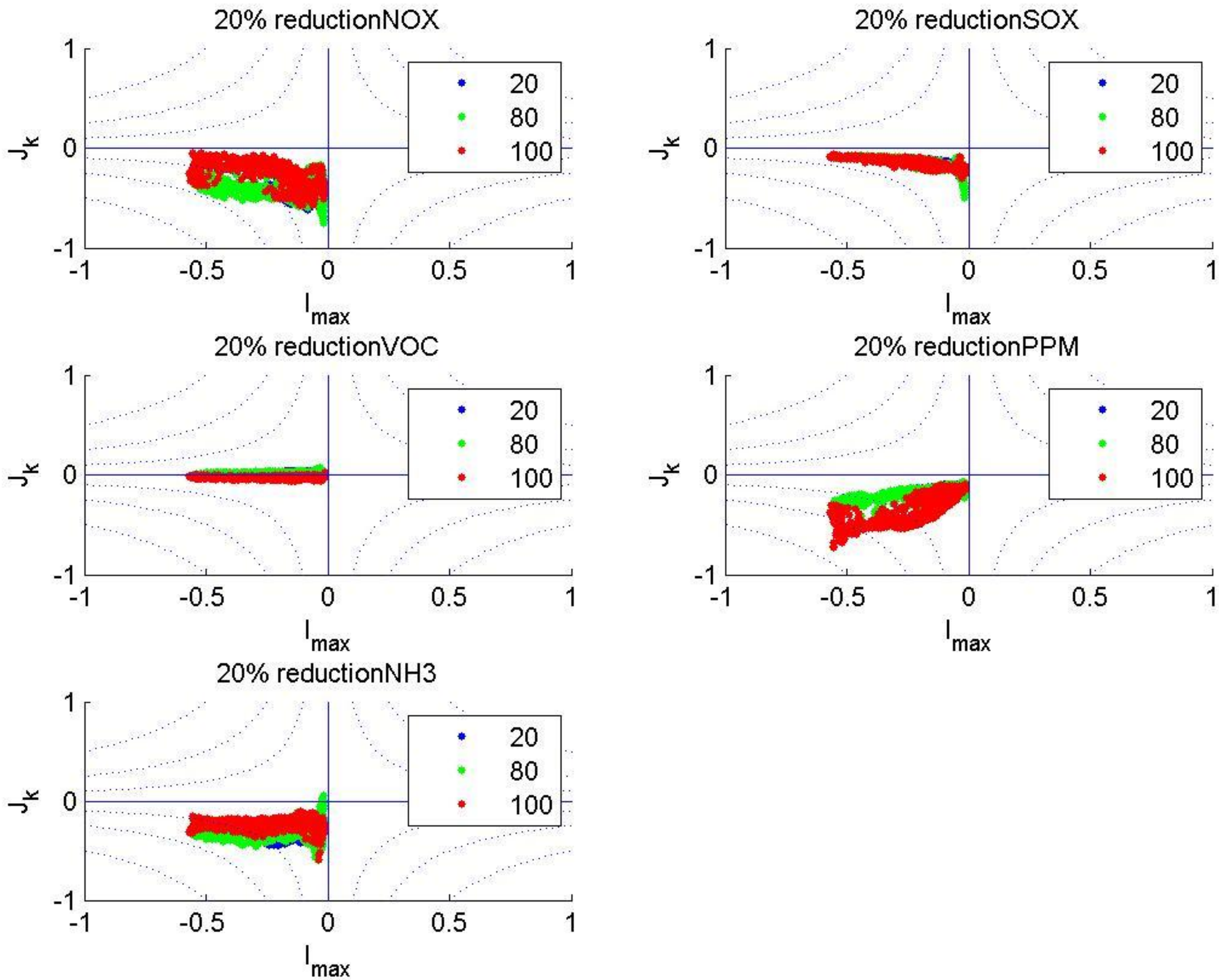
$$\Delta C_{\alpha} / C = 0.5 \times 30\% = 15\%$$

$$\Delta C_{\alpha} / C = 0.5 \times 100\% = 50\%$$

$$J = 0.25$$

a NO_x reduction lead 25% of the maximum reduction

INDICATORS


20% reductionNOX
20% reductionSOX
20% reductionVOC
20% reductionPPM
20% reductionNH3
J_k
I_{max}
1
0
-1
-1
-0.5
0
0.5
1
20
80
100

ROBUSTNESS

The potency is robust if it does not change significantly with the abatement ratio: $p_\alpha \approx p_\beta$

If $\mathrm{I}_{max} = 0.5$ for *20%* emission reduction then

20% emission reduction leads to $\Delta C_\alpha / C = 0.5 \times 20\% = 10\%$ reduction

If I_{max} is robust:

then, *30%* emission reduction leads to $\Delta C_\alpha / C = 0.5 \times 30\% = 15\%$ reduction

40% emission reduction leads to $\Delta C_\alpha / C = 0.5 \times 40\% = 20\%$ reduction

100% emission reduction leads to $\Delta C_\alpha / C = 0.5 \times 100\% = 50\%$ reduction

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ROBUSTNESS and LINEARITY

For a ***single precursor*** the potency is robust when the concentration change linearly with the emission*:*

$$\Delta C_{\alpha_{NOx}} = a.\Delta E_{NOx}$$

$$\frac{\Delta C_{\alpha_{NOx}}}{\Delta E_{NOx}} = a$$

The absolute and relative potencies are, then, constant with the abatement ratio.

The potencies for single precursor can always be split into a linear and a non linear term:

$$p_{\alpha_{NOx}} = p_{\alpha_{NOx}}^{lin} + p_{\alpha_{NOx}}^{nlin}$$

the linear term being robust.

$$p_{\alpha_{NOx}}^{lin} = p_{\beta_{NOx}}^{lin}$$

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ROBUSTNESS and LINEARITY

For ***several precursors*** the potencies can be split into the following terms:

$$p_\alpha = \sum_k p_{\alpha_k} + p_\alpha^{int}$$

$\sum_k p_{\alpha_k}$ is the sum of the potencies of each single precursors (NOx, PPM, VOC, …)

p_α^{int} is a term related to the interaction between the precursors.

In the situation where the interaction term is very small,

if $p_{\alpha_{NOx}} = 0.2$ and $p_{\alpha_{PPM}} = 0.3$ then $p_\alpha = 0.2 + 0.3 = 0.5$

so *20%* NOx emission reduction leads to $\Delta C_{\alpha_{NOx}} / C = 0.2 \times 20\% = 4\%$ reduction

20% PPM emission reduction leads to $\Delta C_{\alpha_{NOx}} / C = 0.3 \times 20\% = 6\%$ reduction

20% NOx and PPM emission reductions lead to $\Delta C_\alpha / C = 4\% + 6\% = 10\%$

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ROBUSTNESS and LINEARITY

Introducing the linear and non linear terms of the single precursor potencies we can write:

$$p_\alpha = \sum_k p_{\alpha_k}^{lin} + \sum_k p_{\alpha_k}^{nlin} + p_\alpha^{int}$$

When the concentration change linearly with the emission of several precursors we have:

$$p_\alpha = \sum_k p_{\alpha_k}^{lin}$$

Consequently, if the concentration change linearly with the emission of several precursors, the potency for these precursors is robust.

But the opposite is not true. We can be in situation where the potency for several precursors is robust but the concentration is not changing linearly with the emissions of these precursors, for example if:

$$\sum_k p_{\alpha_k}^{nlin} = 0$$ and if the interaction terms are constant: $$p_\alpha^{int} = p_\beta^{int}$$

Thank you