European Commission

Training to DGs on Statistical and Participatory Tools for Impact Assessment

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Lecture 2
Sensitivity Analysis of Model Output
A case study

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Case Study SHERPA

Screening for High Emission Reduction Potential on Air

A tool to support the design of regional air quality plans

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JRC - Institute for Environment and Sustainability

European Commission

SHERPA: The Context

- A modeling tool developed by the JRC's *Institute for Environment and Sustainability*

- to quantify air quality in regional/local areas from atmospheric emissions on PM, NO2, NH3, SO2, VOC

- The tool could support the design of air quality policies by EC /MS / local authorities

- Beta version being tested

SHERPA: The Context

1. Policy (ex: 20% reduction of PM due to traffic + 10% reduction of SO_2 from industry)

2. SHERPA: Emissions reduction (Delta E) → Air quality improvement (concentrations reduction – Delta C)

3. Other models to compute socio-economic impacts (years of lost life)

4. RIAT model (Regional integrated assessment tool by JRC and others) to assist the policy makers in identifying the possible interventions needed to achieve the desired emissions reductions policies

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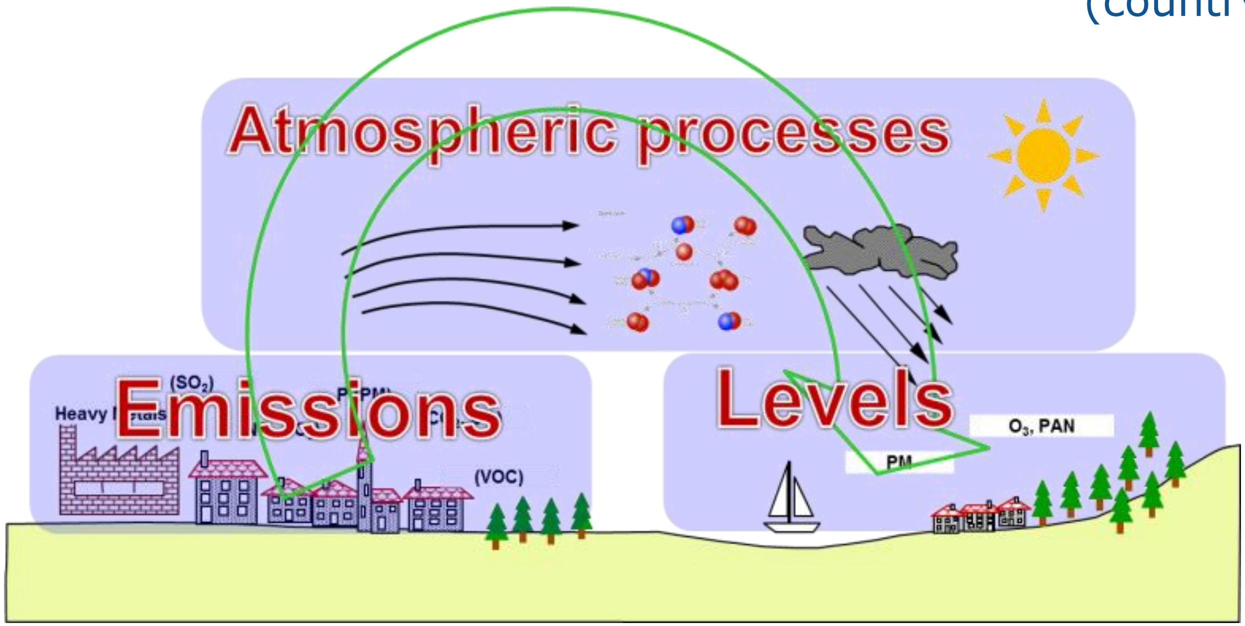
The SHERPA Model

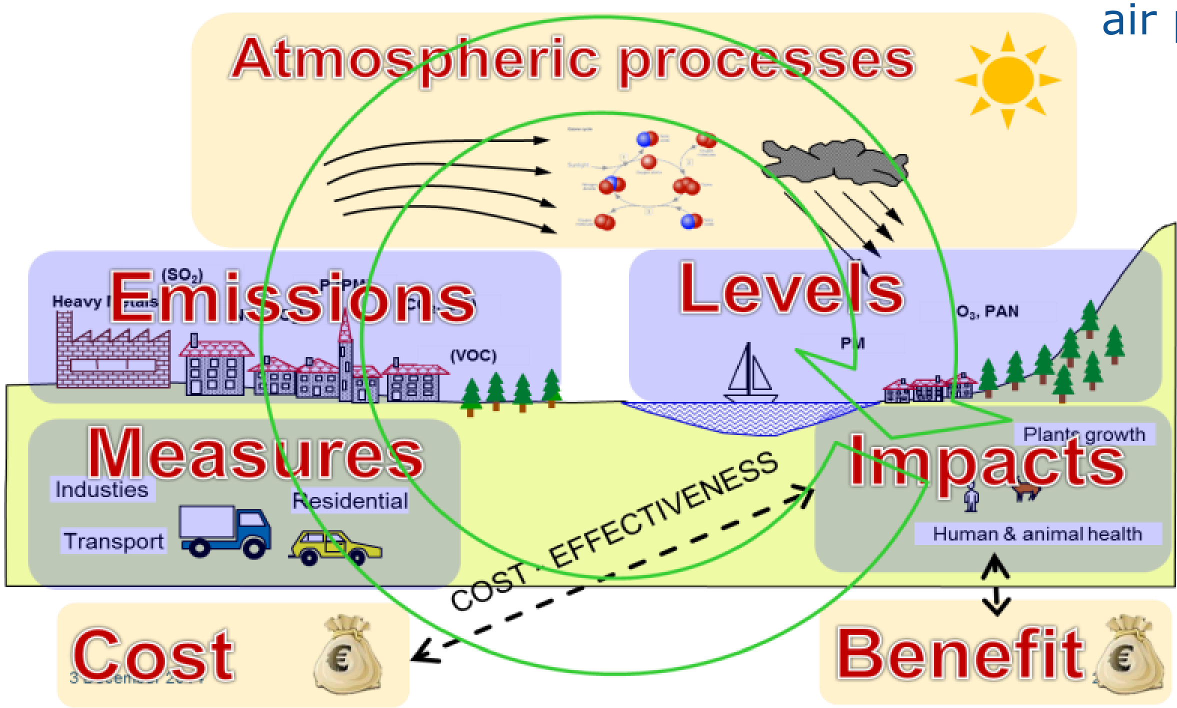
Questions addressed

- Is there a potential for action ?
- Which sector/pollutant should be prioritized?
- What is the best scale for action (country, region…)?



SHERPA is meta-model estimated from a complex physics-based transport model CHIMERE developed by INERIS (F)

SHERPA + RIAT Models

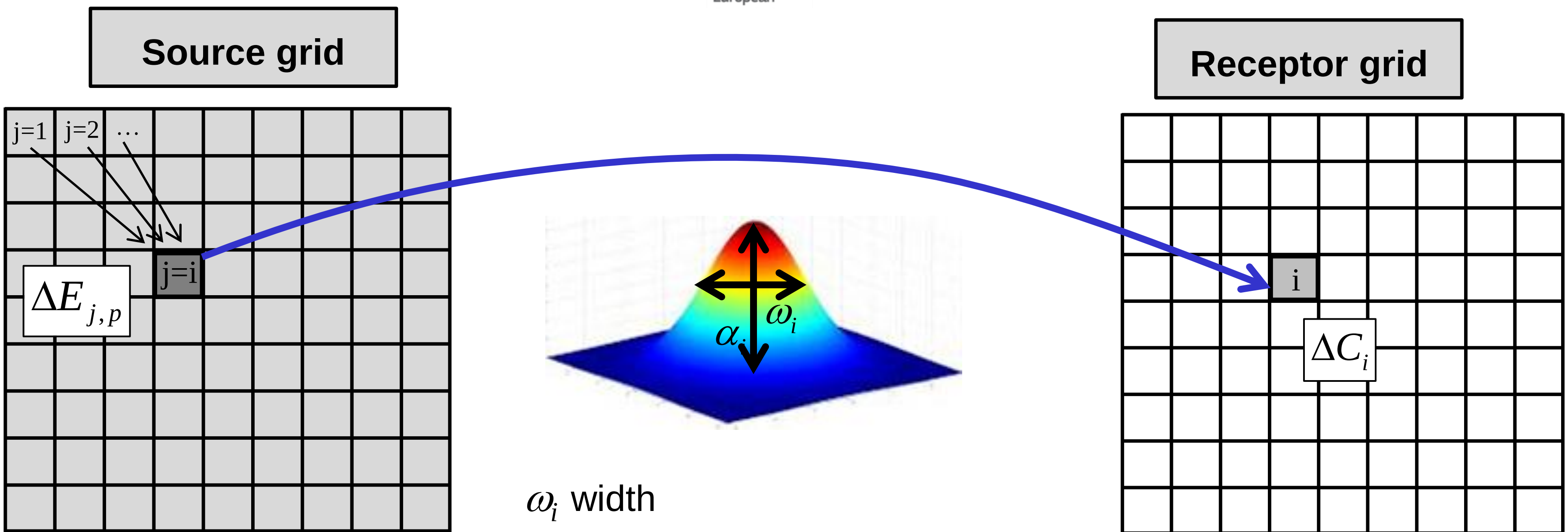


Questions addressed

- For a given budget, what is the best set of measures to reduce air pollution at most?

- Support DG's Air Quality impact assessment at regional/urban scales
- Support Regional Authorities in designing and assessing AQ plans

Key module of the system



$\Delta E_i (KTonnes)$

$\Delta C_i (\mu g/m^3)$

ω_i width

α_i amplitude

d_{ij} is the distance between the receptor *i* and each source cell *j*.

$$\Delta C_i = \sum_{p=1}^{n_p} \alpha_{i,p} \sum_{j=1}^{n} \left(1 + d_{ij}\right)^{-\omega_{i,p}} \Delta E_{j,p}$$

$\alpha_{i,p}$ and $\omega_{i,p}$ are parameters

i: NOX, NH3, PM, SO2

$\alpha_{i,p}$ and $\omega_{i,p}$ are estimated with an uncertainty bound using least squares between the emulator's output and the large model's output

The uncertainty in $\alpha_{i,p}$ and $\omega_{i,p}$ propagates through the model and affects the output ΔC.

The uncertainty of ΔC should be as small as possible to provide a robust inference that can be used for policy.

$$\Delta C_i = \sum_{p=1}^{n_p} \alpha_{i,p} \sum_{j=1}^{n} \left(1 + d_{ij}\right)^{-\omega_{i,p}} \Delta E_{j,p}$$

For example if:

Policy 1 → $\Delta C = 4 \div 7$

Policy 2 → $\Delta C = 3 \div 8$

the inference is not robust enough to conclude whether one policy is better than another.

Is there a way to reduce the uncertainty bounds of ΔC for each policy?

Perform sensitivity analysis and see.

Emission reductions policies:

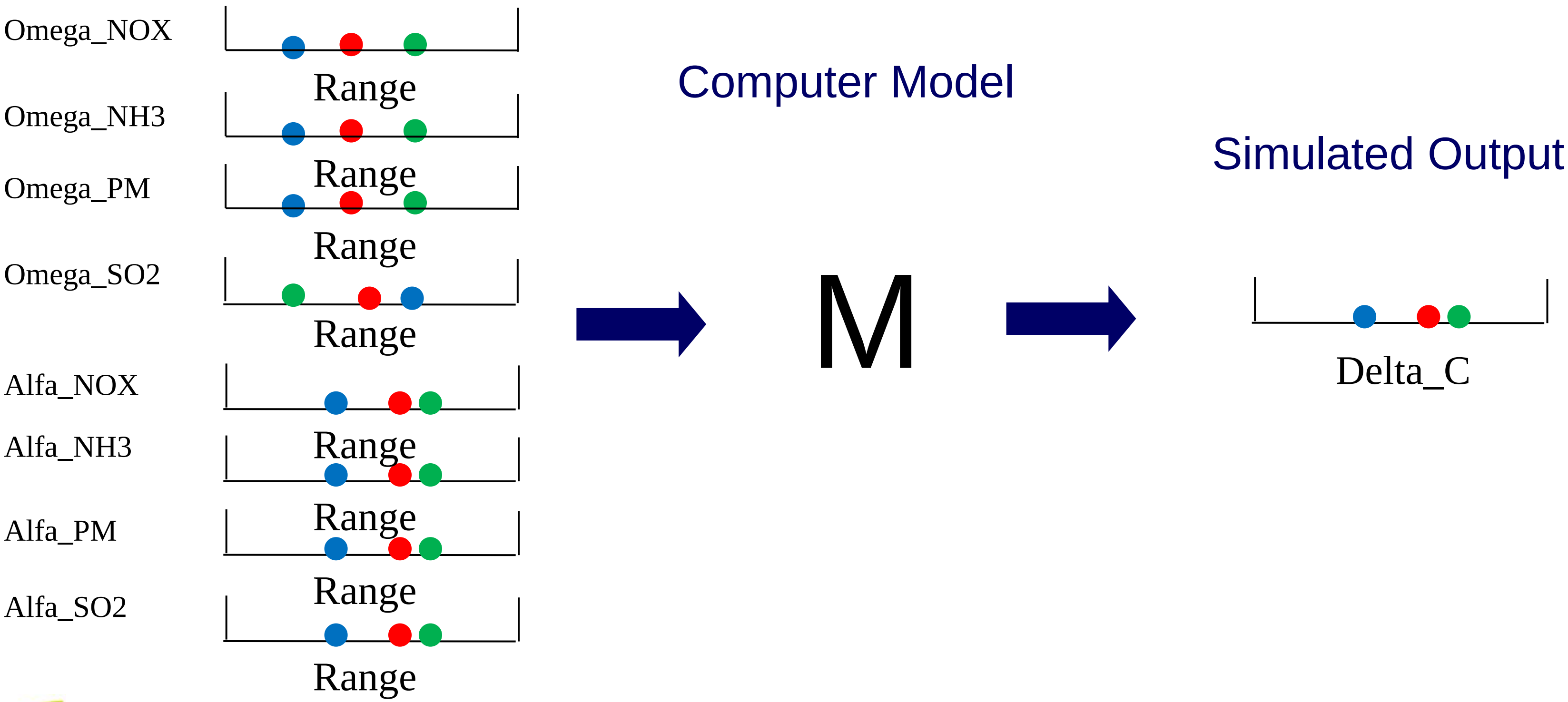
- "deltaE, 0-0-0-0" (status quo)
- "deltaE, 75-25-25-25" (75% reduction for NOx, 25% for NH3, 25% for PM, 25% for SO2)
- "deltaE, 25-25-25-75"
- "deltaE, 100-100-100-100" (maximum feasible reduction using best available technology)
- Etc.

Case Study: Milan area – input parameters

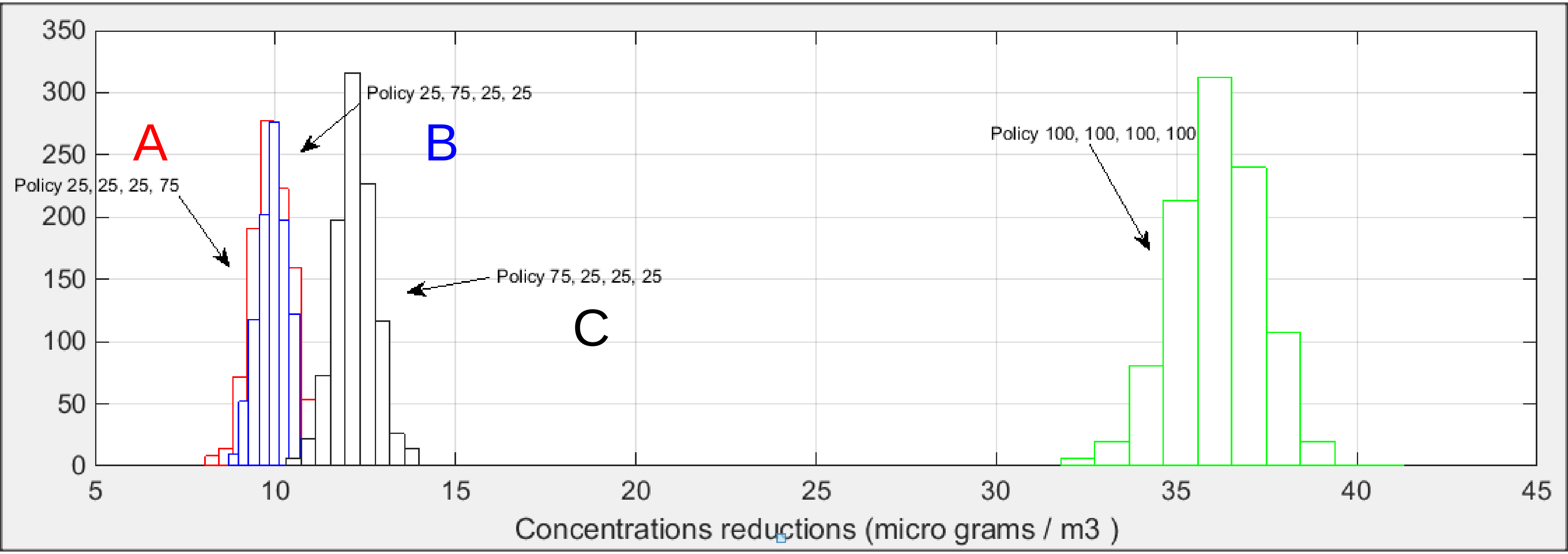
A	B	C	D
45.5313	LAT		
9.1875	LON		
200	cells case (slow computation)		
	Estimated mean	Estimated standard deviation	
omega_nox	1.9728	0.0221	
omega_nh3	1.6005	0.0202	
omega_ppm	2.3294	0.0173	
omega_so2	1.3397	0.0091	
alpha_nox	0.0497	0.005	
alpha_nh3	0.0679	0.0133	
alpha_pm25	1.9693	0.0422	
alpha_so2	0.0123	0.0047	

Uncertainty analysis

Sample size ≈ 30,000 points

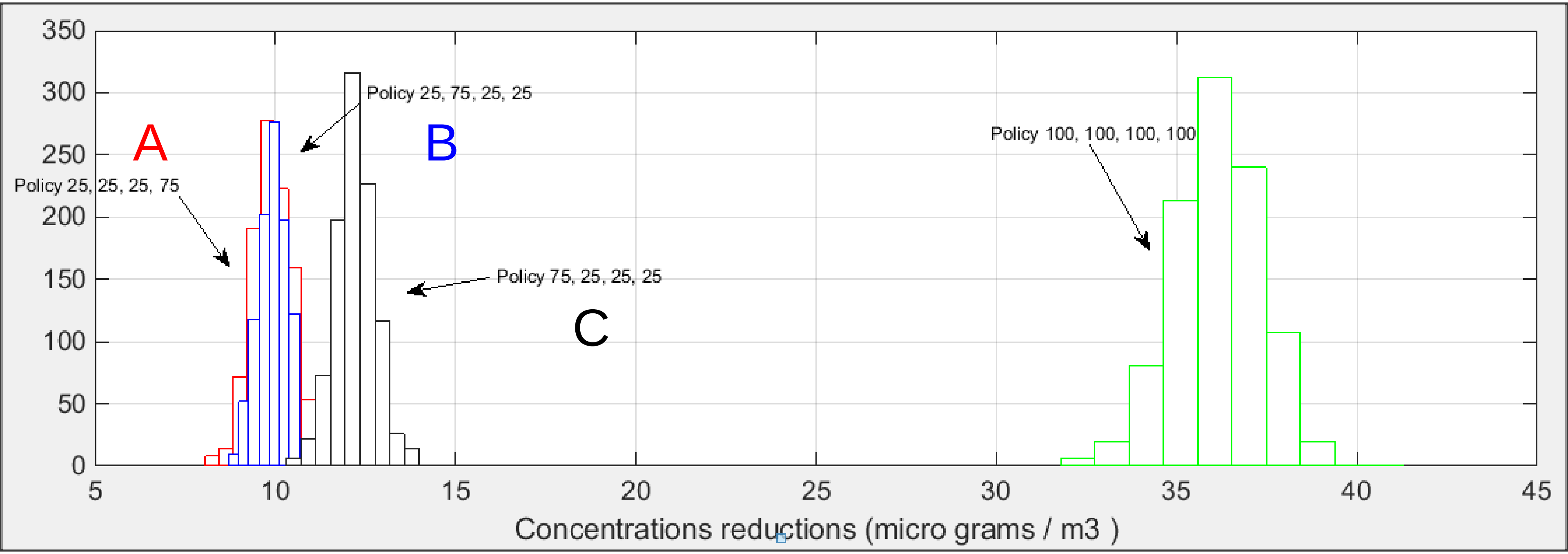


Uncertainty Analysis



A and B seem to have the same impact. We should then choose the less expensive to implement.

Uncertainty Analysis



We may want to reduce the uncertainty bounds of ΔC for A and B to have more accurate impacts and to see whether they split (and possibly conclude that one is better than the other)? To this aim, which is the most efficient input to act upon?

Sensitivity Analysis: Total indices

Policy Profile	Total Order Sensitivity Indices								Sum
	om_NOX	om_NH3	om_PM	om_SO2	alfa_NOX	alfa_NH3	alfa_PM	alfa_SO2	
100-100-100-100	0.01	0.01	0.11	0.01	0.24	0.09	0.16	0.35	0.98
C: 75-25-25-25	0.04	0.00	0.03	0.01	0.69	0.03	0.04	0.11	0.95
B: 25-75-25-25	0.00	0.05	0.06	0.01	0.13	0.45	0.09	0.20	0.99
A: 25-25-25-75	0.01	0.01	0.11	0.01	0.24	0.09	0.16	0.35	0.98

The most efficient way to get more precise concentrations is to reduce uncertainty of the alpha's. Better estimation of alpha's will supply more accurate delta C. Do not try to estimate the omega's: you will not have any gain. Do not waste time trying to get better info on the omega's.

The model is additive: no interactions, no surprises

Sensitivity Analysis

Policy Profile	Total Order Sensitivity Indices								Sum
	om_NOX	om_NH3	om_PM	om_SO2	alfa_NOX	alfa_NH3	alfa_PM	alfa_SO2	
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These values are not in contrast with the belief of the modeller/expert.

One can defend the model results against falsification (e.g., one saying that different values of omega would have given completely different values of conentrations).

Sensitivity Analysis

Policy Profile	**Total Order Sensitivity Indices**								**Sum**
	om_NOX	om_NH3	om_PM	om_SO2	alfa_NOX	alfa_NH3	alfa_PM	alfa_SO2	
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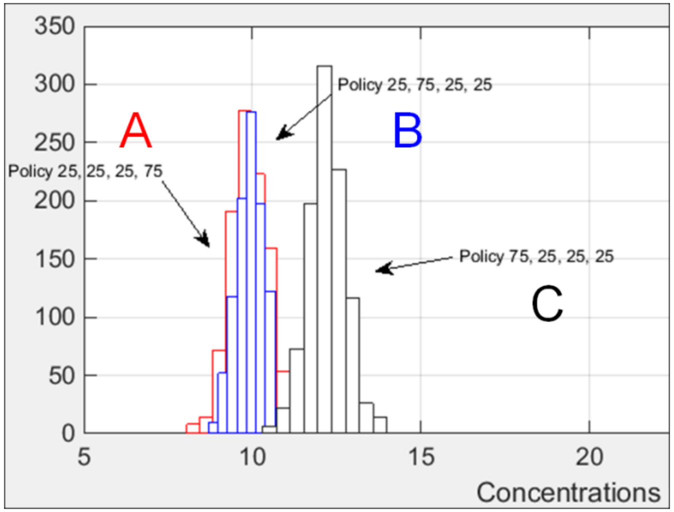
SA gives useful info about whether the model should be revisited. For example, the modeller made the assumption that all SO2 emissions occur at ground level, whilst this is not true for power plants. Being alfa_SO2 important, this assumption should be revisited because a modification in alfa_SO2 might have important repercussions on model output.

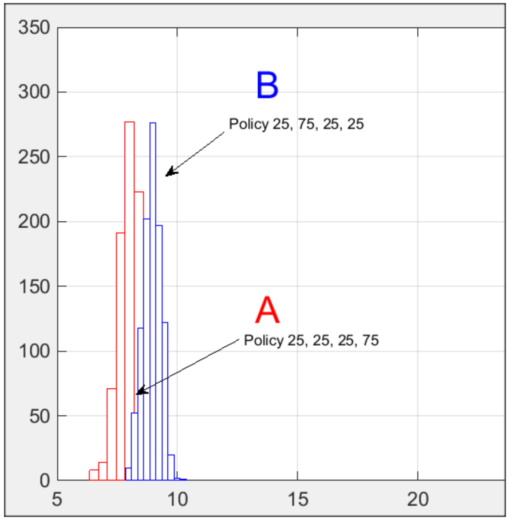
Uncertainty Analysis (II stage)

Let us assume that we have successfully updated estimation of alfa_SO2 and reduced its uncertainty of about 50% thanks to additional observations (ie runs of the large model). What are the new bounds for delta C's? Is now a policy decision possible?

Before



After



Thank you.
Any questions?

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