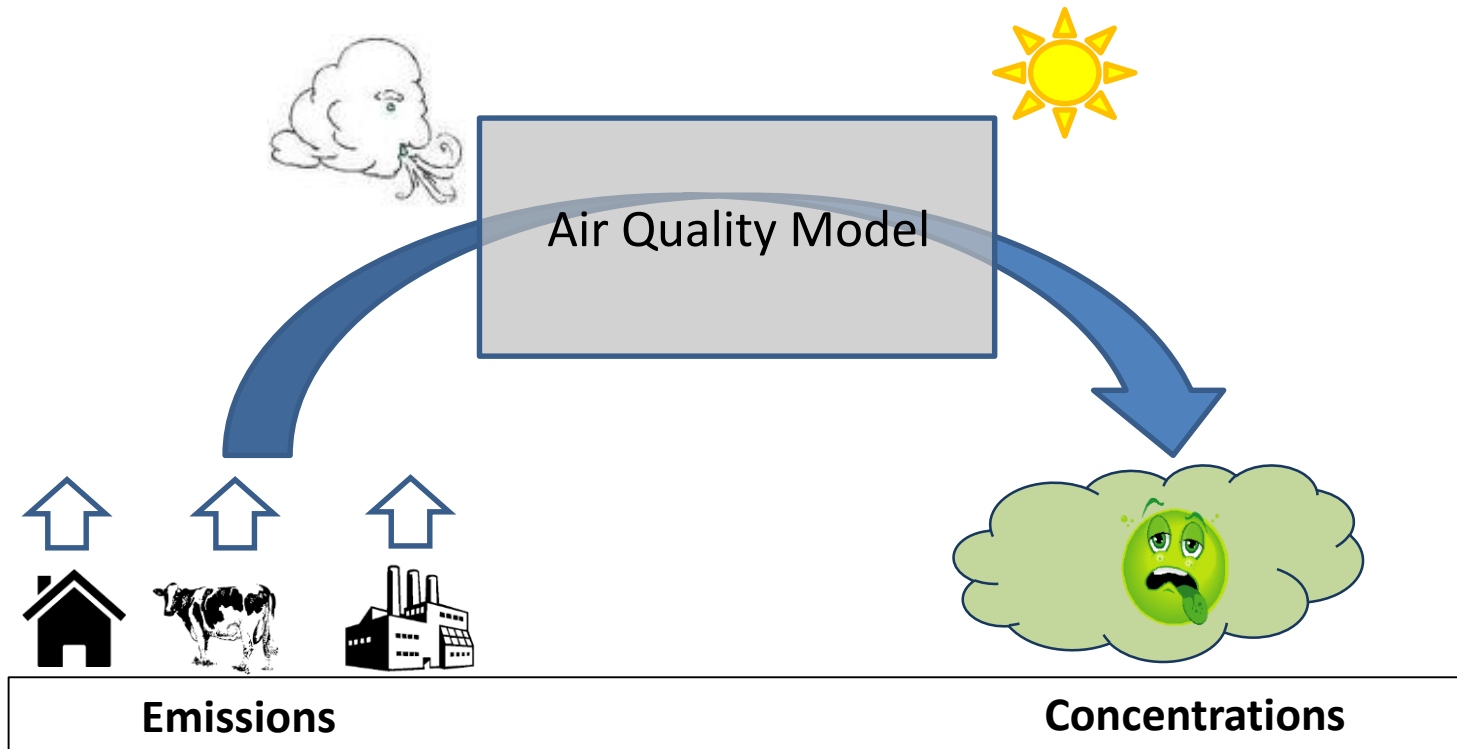


Source Apportionment and Planning: What & when is it fit for purpose?

A. Clappier, D. Pernigotti, C. Belis, P. Thunis

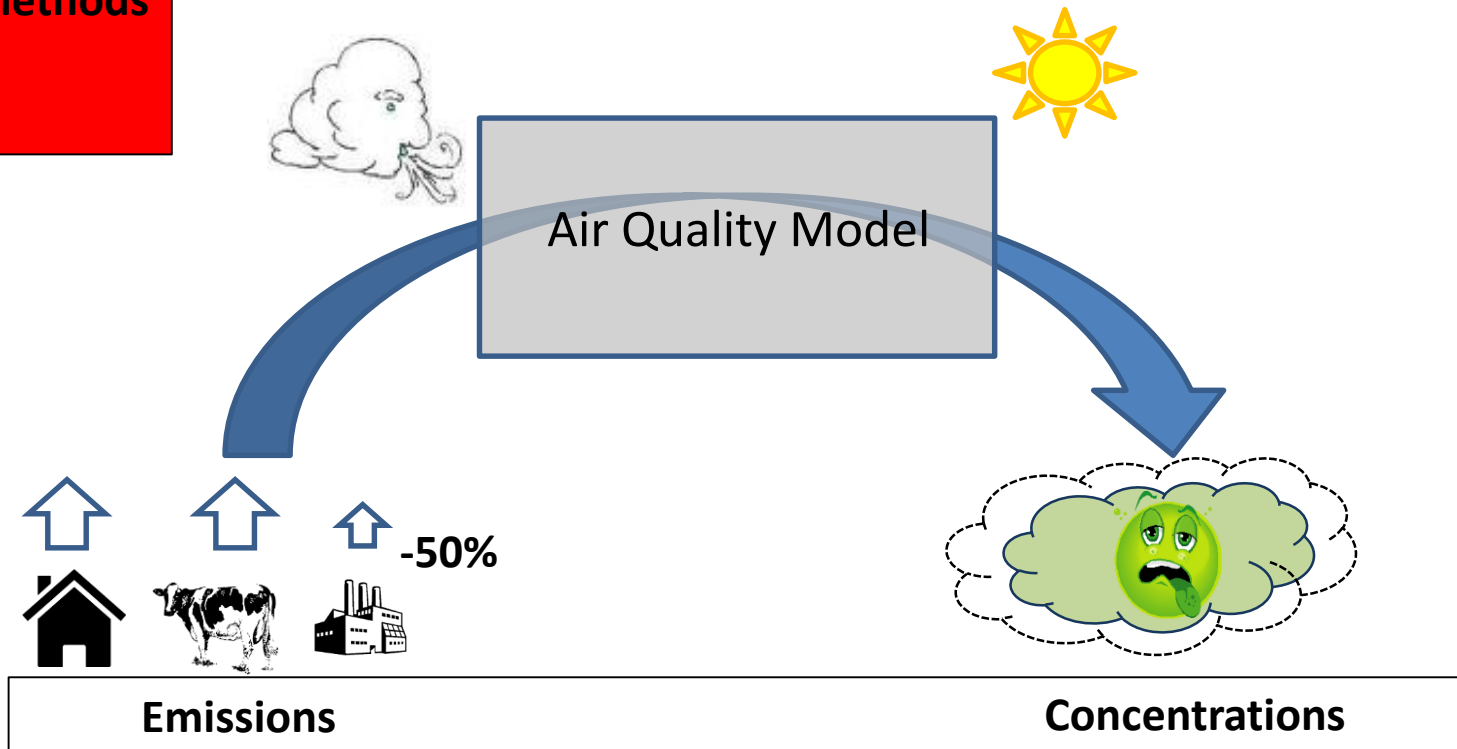
Air Quality Models



Planning

Brut Force methods

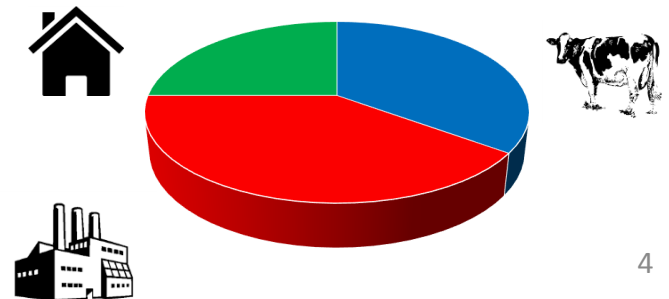
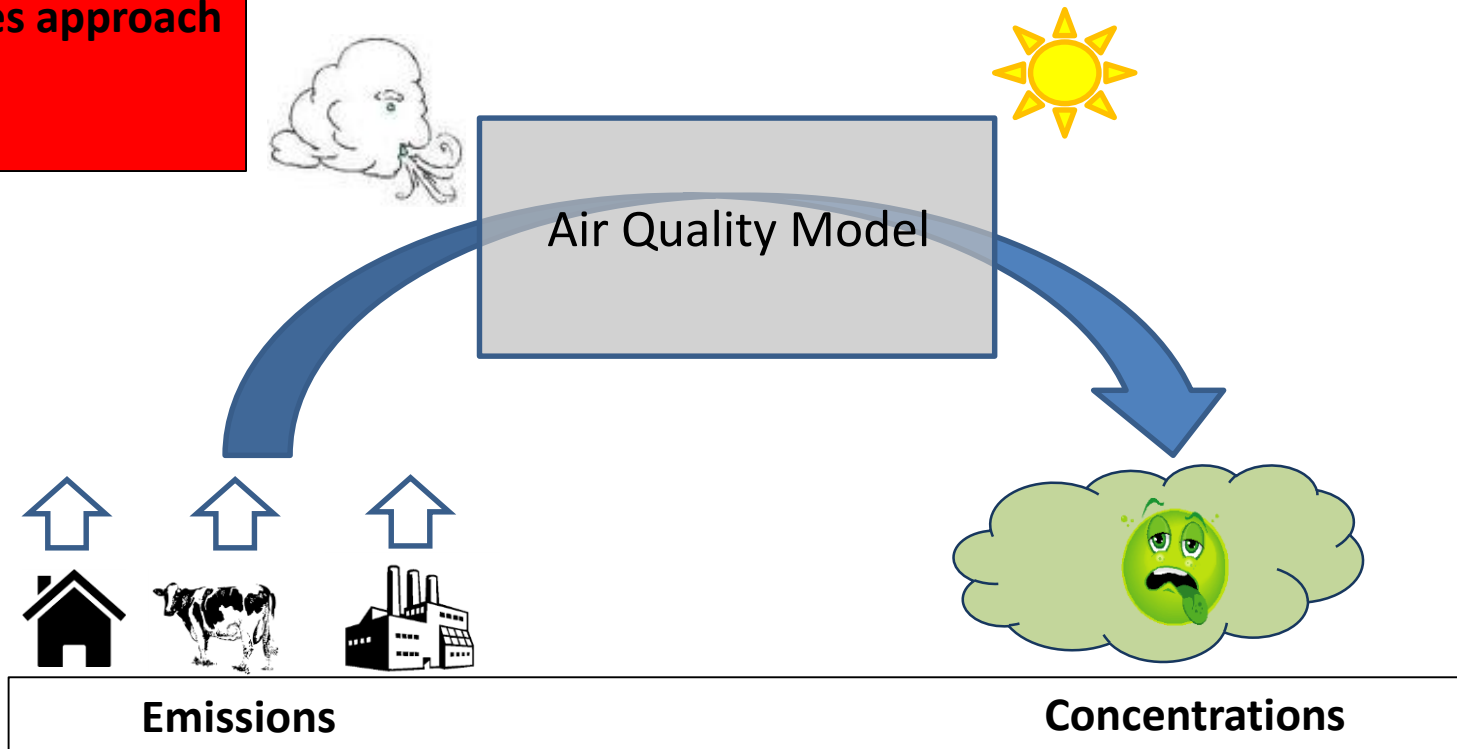
DDM



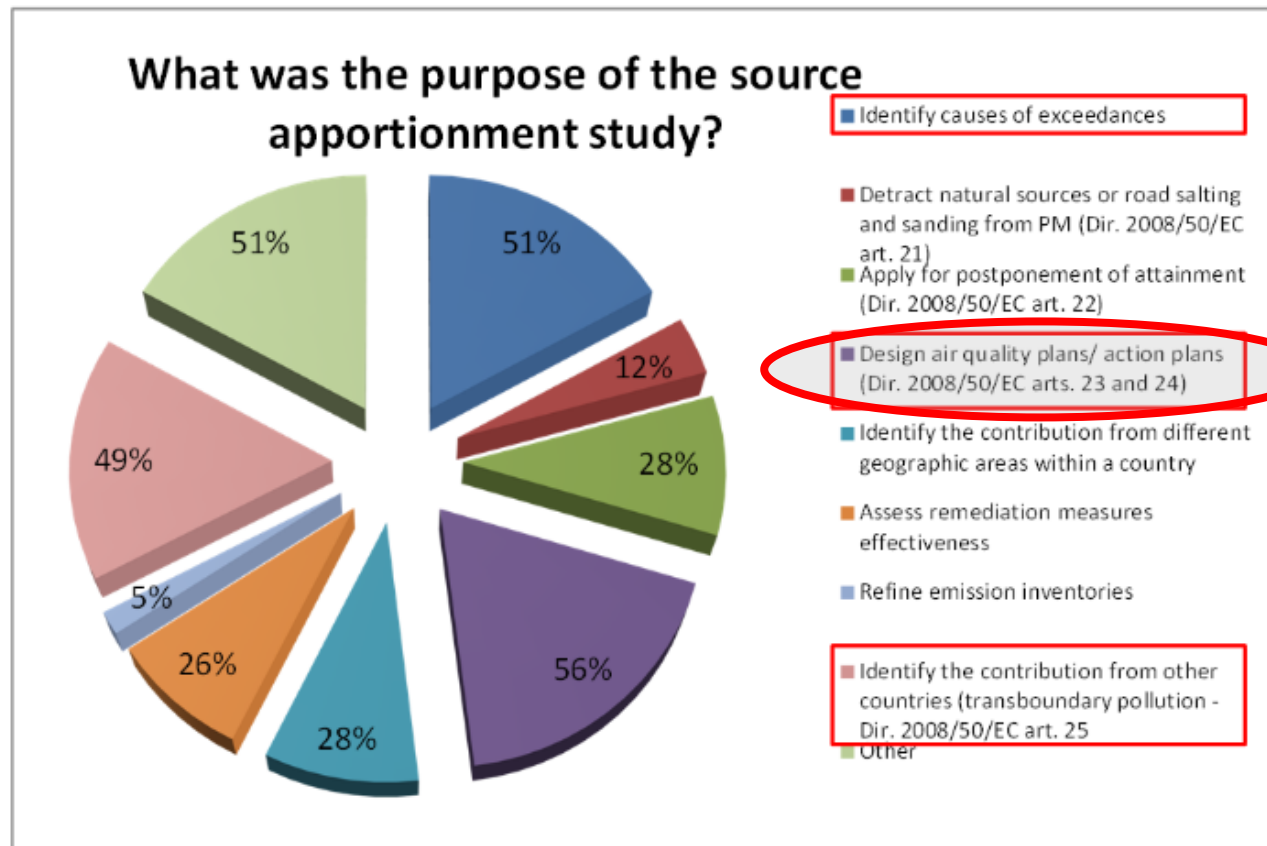
Source apportionment

Tagged species approach

PSAT



Source apportionment in integrated assessment studies



The main reasons are associated to obligations deriving from the AQD:

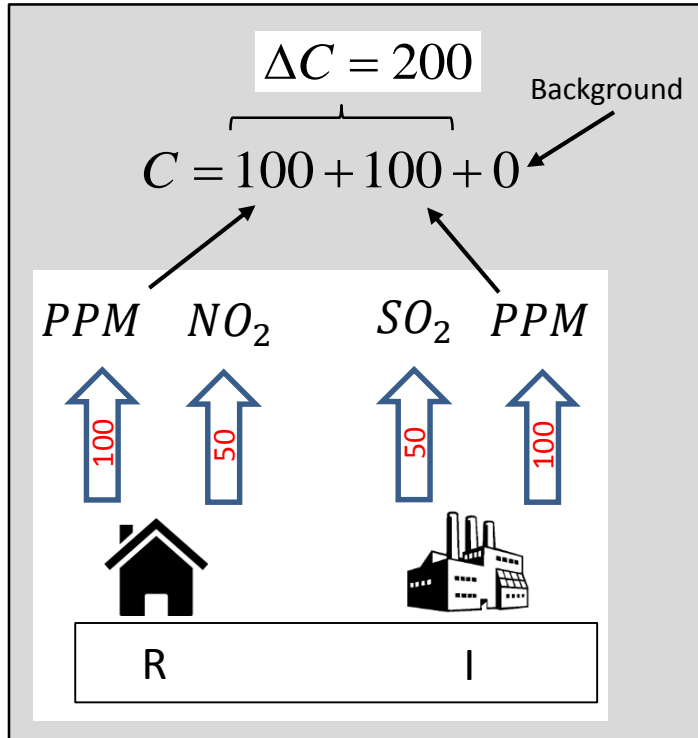
- to design air quality plans or action plans,
- to identify the causes of exceedances, and
- to identify transboundary pollution

Source: Appraisal deliverable 2.6 - <http://www.appraisal-fp7.eu>

Question

Can we use source apportionment to design air quality plans ?

Example: linear case



Source apportionment estimates **contributions** of the different sources:

$$\delta C_R = 100$$

$$\delta C_I = 100$$

$$\delta C_R + \delta C_I = 200 = \Delta C$$

Planning estimates **impacts** of the different sources:

100% reduction: $\Delta C_R = 100$

$\Delta C_I = 100$

$\Delta C_R + \Delta C_I = 200 = \Delta C$

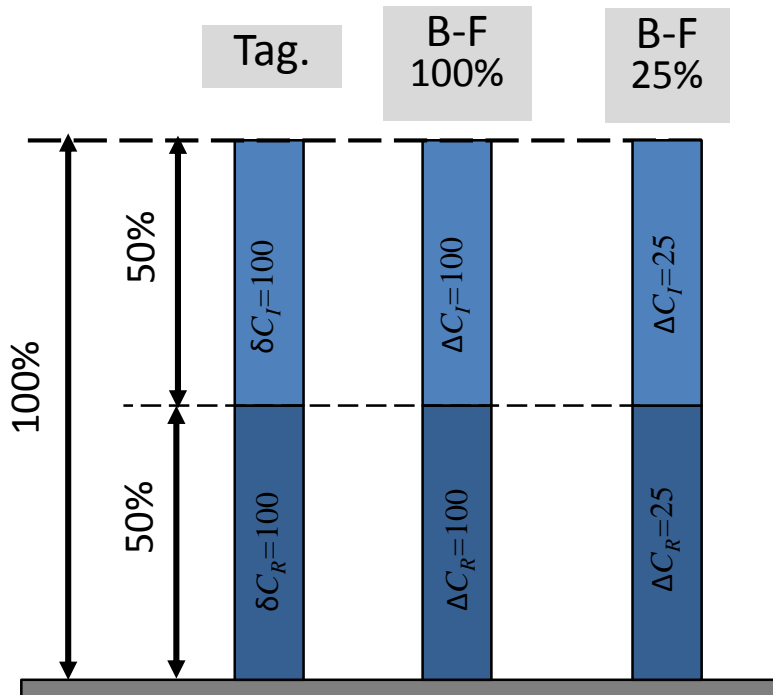
25% reduction: $\Delta C_R = 25$

$\Delta C_I = 25$

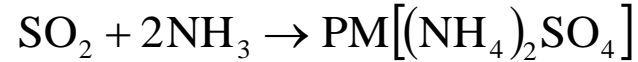
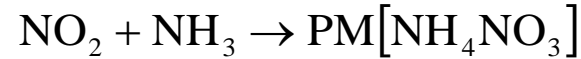
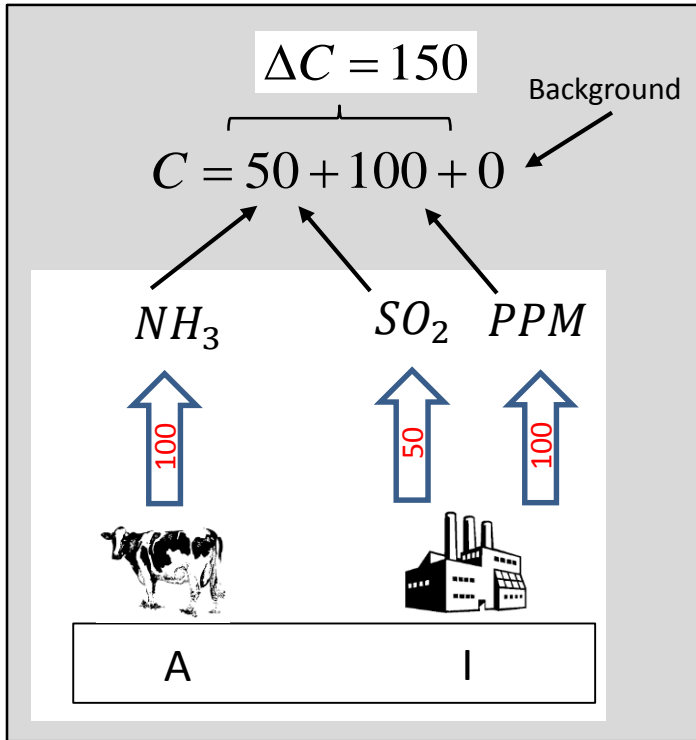
$\Delta C_R + \Delta C_I = 50 = \Delta C$

Example: linear case

Source apportionment	$\Delta C = 200$	$\delta C_R = 100$	$\delta C_I = 100$
Planning 100% red.	$\Delta C = 200$	$\Delta C_R = 100$	$\Delta C_I = 100$
Planning 25% red.	$\Delta C = 50$	$\Delta C_R = 25$	$\Delta C_I = 25$



Example: non linear case



Source apportionment estimates **contributions** of the different sources:

$$\delta C_A = 50 \times (1 - 0.73) = 13.5$$

$$\delta C_I = 50 \times 0.73 + 100 = 136.5$$

$$\delta C_A + \delta C_I = 150 = \Delta C$$

Planning estimates **impacts** of the different sources:

100% reduction: $\Delta C_A = 50$

$\Delta C_I = 150$

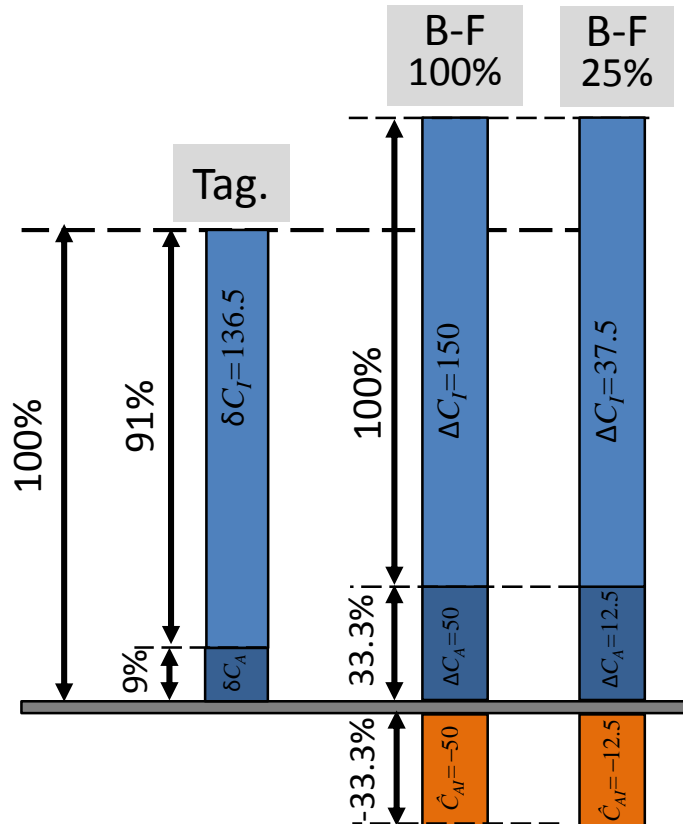
$\Delta C_A + \Delta C_I = 200 \neq \Delta C$

$$\Delta C = \Delta C_A + \Delta C_I + \hat{C}_{AI}$$

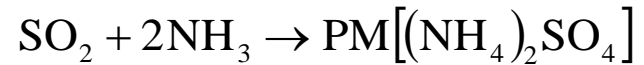
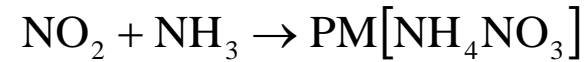
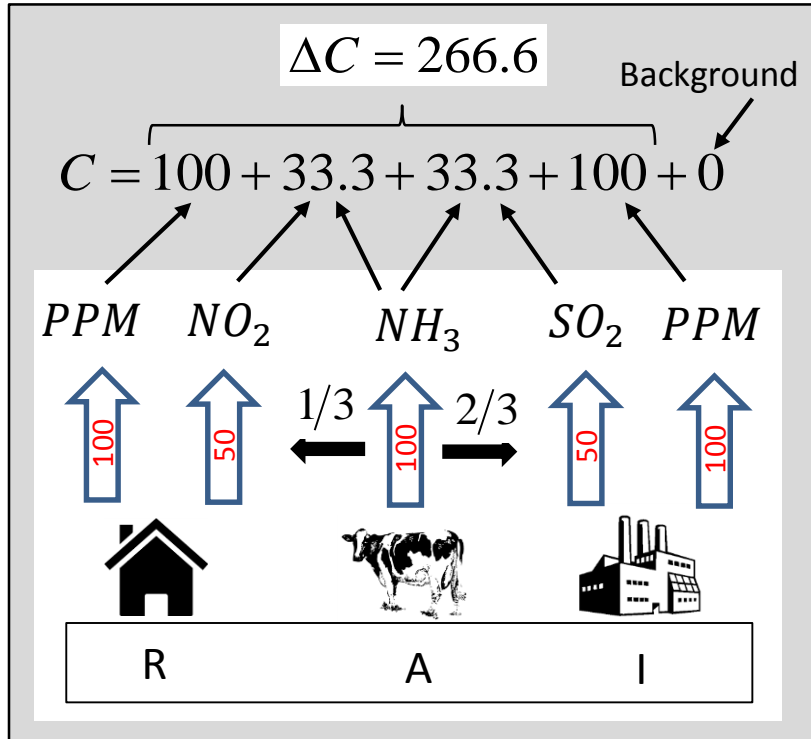
$$\hat{C}_{AI} = -50$$

Example: non linear case

Source apportionment	$\Delta C = 150$	$\delta C_A = 13.5$	$\delta C_I = 136.5$	
Planning 100% red.	$\Delta C = 150$	$\Delta C_A = 50$	$\Delta C_I = 150$	$\hat{C}_{AI} = -50$
Planning 25% red.	$\Delta C = 37.5$	$\Delta C_A = 12.5$	$\Delta C_I = 37.5$	$\hat{C}_{AI} = -12.5$



Example: non linear case



Source apportionment estimates **contributions** of the different sources:

$$\delta C_R = 100 + 33.3 \times 0.78 = 125.8$$

$$\delta C_A = 33.3 \times (1 - 0.78) + 33.3 \times (1 - 0.73) = 16.6$$

$$\delta C_I = 100 + 33.3 \times 0.73 = 124.2$$

$$\delta C_R + \delta C_I + \delta C_A = \Delta C$$

Planning estimates **impacts** of the different sources:

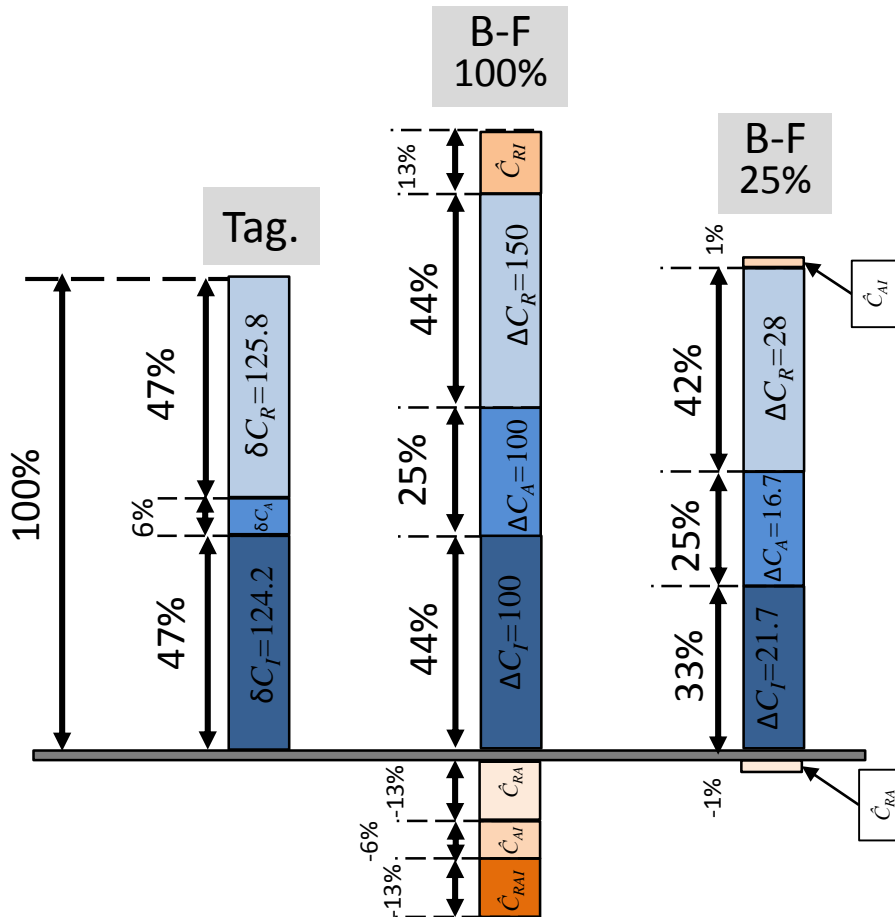
$$\Delta C_R = 116.7 \quad \Delta C_A = 67.6 \quad \Delta C_I = 116.7 \quad \Delta C_R + \Delta C_A + \Delta C_I = 300 \neq \Delta C$$

$$\Delta C = \Delta C_R + \Delta C_A + \Delta C_I + \hat{C}^{int}$$

$$\hat{C}^{int} = -33.3 = \hat{C}_{RA} + \hat{C}_{RI} + \hat{C}_{AI} + \hat{C}_{RAI}$$

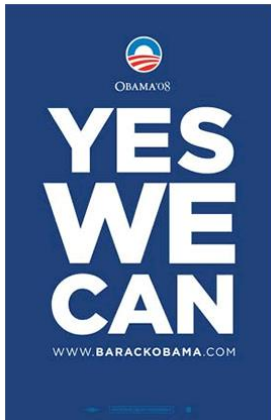
Example: non linear case

Source apportionment	$\Delta C = 266.6$	$\delta C_R = 125.8$	$\delta C_A = 16.6$	$\delta C_I = 124.2$
Planning 100% red.	$\Delta C = 266.6$	$\Delta C_R = 116.7$	$\Delta C_A = 67.6$	$\Delta C_I = 116.7$
Planning 25% red.	$\Delta C = 66.7$	$\Delta C_R = 28$	$\Delta C_A = 16.7$	$\Delta C_I = 21.7$



Answer

Can we use source apportionment to design air quality plans ?



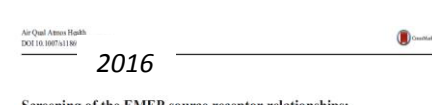
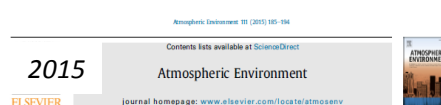
BUT it must be “close enough” to linearity:



if not...



WG4 recommendation: Indicators



Indicators to support the dynamic evaluation of air quality models

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HIGHLIGHTS

- Proposed indicators to evaluate air quality models for dynamic evaluation.
- Proposed diagrams to evaluate emission reduction impacts on concentrations.
- Assessment of the robustness and non-linearity of model responses.
- Diagram and indicators are useful for policy-maker and model developers.

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Keywords:
 Dynamic evaluation
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 Performance indicators

Quantification of non-linearities as a function of time averaging in regional air quality modeling applications

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HIGHLIGHTS

- Methodology to quantify non-linearities in air quality models responses.
- The non-linearity quantification methodology is applied to daily, monthly and yearly averaged concentrations.
- Seasonal dependencies are analyzed for both PM10 and O3 compounds.
- Quantification of non-linearity is useful for policy-maker to ensure robust strategies.

ARTICLE INFO

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Keywords:
 Non-linearity
 Air quality modeling
 Photochemistry
 Time averaging
 Integrated assessment modeling
 Singular models

Air quality models which are nowadays used for a wide range of scopes (i.e. assessment, forecast, planning) see their internal complexity progressively increasing as better knowledge of the atmospheric chemistry processes is gained. As a result of this increased complexity non-linearities are implicitly and/or explicitly incorporated in the system. These non-linearities represent a key and challenging aspect of air quality modeling, especially to assess the robustness of the model response. In this work the importance of non-linear effects in air quality modeling is quantified, especially as a function of time averaging. A methodology is proposed to decompose the concentration change resulting from an emission reduction on a given domain into its linear and non-linear contributions for each precursor as well as in the contribution resulting from the interactions among precursors. Simulations with the LOTOS-EUROS model have been performed by TNO over three regional atmospheric areas in Europe for the analysis. In all three regions the non-linear effects for PM₁₀ and PM_{2.5} are shown to be relatively more for yearly and monthly averages whereas they become significant for daily average values, for Ozone non-linearity becomes important already for monthly averages in some regions. An approach which explicitly deals with monthly variations seems therefore more appropriate for O₃. In general non-linearities are more important for forecasting than for assessment and planning.

Dynamic evaluation of air quality models over European regions

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HIGHLIGHTS

- Air quality model responses to emission reduction scenarios are presented.
- Maximum potential for local emission abatement is identified.
- Relative importance of the various precursor emissions is assessed.
- Degree of non-linearity of the model responses is estimated.
- These case studies in Europe are considered.

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 Emission reductions
 Non-linearity

ABSTRACT

Chemistry-transport models are increasingly used in Europe for estimating air quality or forecasting changes in pollution levels. But with this increased use of modeling arises the need of harmonizing the methodologies to determine the quality of air quality model applications. This is complex for planning applications, i.e. when models are used to assess the impact of realistic or virtual emission scenarios. In this work the methodology based on the calculation of precursors proposed by Thunis and Clappier (2014) to analyze the model responses to emission reductions is applied on three different domains in Europe (Po Valley, Southern Rhodan and Flanders). This methodology is further evaluated to facilitate the inter-comparison process and bring in a single diagram the possibility of differentiating long-term from short-term effects. This methodology is designed for model users to interpret their model results but also for policy-makers to help them defining intervention priorities. The methodology is applied to both daily PM₁₀ and 8 h daily maximum ozone.

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1. Introduction

Air quality models are increasingly used in Europe for simulating air quality. In the past, assessment and reporting of air quality was largely based on monitoring data but the situation has changed in recent years when more emphasis has been put on the use of air quality models to complement monitoring data. This is the result, among others, of the 2008 European Directive on Ambient Air Quality and Cleaner Air for Europe which encourages modeling as one of the means to perform AQ management tasks such as air quality assessment, forecasting and planning (EA, 2011). With increasing number of air quality modeling applications, the need of harmonizing the methodologies to check the quality of air quality model applications is high. It is in this context that validation procedures are currently being developed in the frame of the Forum for Air Quality Modeling – FARMORE initiative (<http://farmore.jrc.ec.europa.eu/>). Since air quality models can be used to perform various tasks (assessment, forecasting, planning, specific validation protocols (i.e. Dennis et al., 2010, i.e. for assessment) should be developed and used.

Regarding assessment (or operational model evaluation, i.e. the reconstruction of past/prevent pollution episodes) the validation procedure usually makes use of real measurement at monitoring stations, that allows quantifying the quality of a given model simulation. In this context various protocols have already been developed (e.g., Delta Tool, <http://agm.jrc.ec.europa.eu/> (Delta), see Thunis et al., 2012; Caravello et al., 2014; Dennis et al., 2010, etc.). Regarding forecasting (i.e. the application of a model to forecast

Screening of the EMEP source receptor relationships: application to five European countries

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Abstract In this work, a methodology based on the calculation of precursors and potentials is used to screen modeled emission reduction scenarios performed with the European Monitoring and Evaluation Programme/Meteorological Synthesizing Centre-West (EMEP/MSC-W) air quality model. Specific indicators are proposed to look at the results in terms of model processes (potentials) as well as in terms of their impacts on policy (potentials). A specific template to screen the results is also developed and applied. The EMEP/MSC-W model results obtained for 5 EU countries for 5 precursors and 2 levels of emission reductions (15 and 40 %) are analyzed with the following purpose: (i) build confidence in the processes implemented in the model; (ii) identify potential for national abatement versus trans-boundary transport; (iii) assess the relative importance of various precursor emissions; and (iv) estimate the importance of non-linearity with respect to the level of emission reduction changes and among the precursor emissions. The proposed methodology proves to be very useful for comparing the responses across countries and precursors in a uniform way. The results confirm our knowledge in terms of processes implemented and among the precursor emissions. The proposed methodology proves to be very useful for comparing the responses across countries and precursors in a uniform way. The results confirm our knowledge in terms of processes implemented and among the precursor emissions. The proposed methodology proves to be very useful for comparing the responses across countries and precursors in a uniform way.

Keywords Air quality modeling · Integrated assessment · Source receptor relationships · Non-linearity

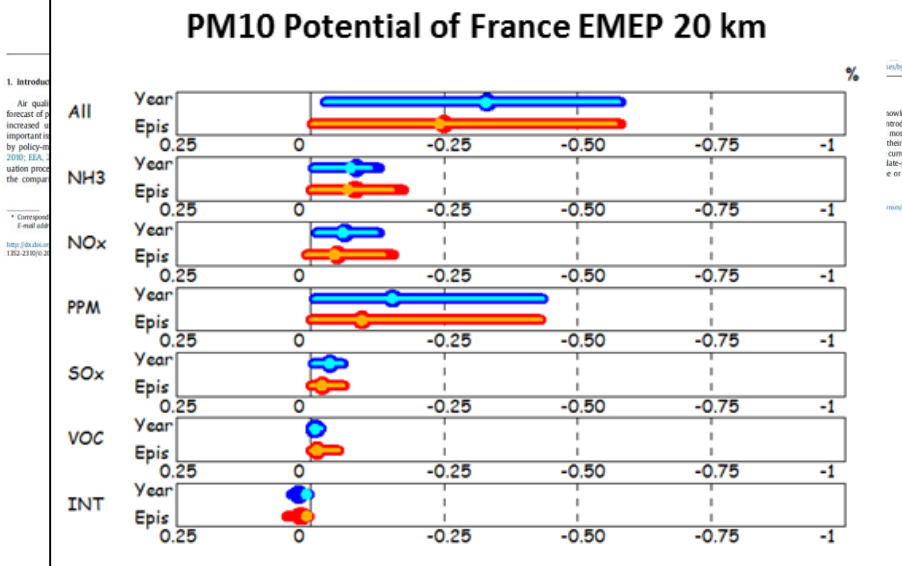
non-linearities with respect to NH₃ (all countries) and NO_x (in Italy) are observed. Because no reference can be used to assess the quality of the model results in scenario mode, it is important to consider this screening as a benchmark to which other models or updated versions of the EMEP/MSC-W model can be compared to in the future.

Keywords Air quality modeling · Integrated assessment · Source receptor relationships · Non-linearity

Introduction

Models are increasingly used in Europe for simulating air quality. This is the result, among others, of the 2008 European Directive on Ambient Air Quality and Cleaner Air for Europe (AQD 2008) which encourages modeling as one of the means to perform air quality management tasks (EA, 2011). Indeed, when and whenever EU limit thresholds are exceeded, authorities have a formal obligation to design air quality plans. Models are then very useful to support air quality management and in particular assess the impact of those plans on air quality. The same holds at the European scale where the European Monitoring and Evaluation Programme/Meteorological Synthesizing Centre-West (EMEP/MSC-W) air quality model (Stempson et al., 2012) feeds the RAINS/GAINS integrated assessment modeling tool (Amann et al., 2011) to balance emission reductions across countries in a cost-efficient manner.

With this increased use of air quality modeling in the frame of policy support, ensuring that models are accurate and robust becomes essential. It is in this context that validation protocols are currently being developed in the frame of the Forum for Air Quality Modeling (FARMORE) initiative¹. Specific evaluation



Use the indicators to quantify the non linearity.

WG4 recommendation: Indicators

Non linearity decreases with long time averaging

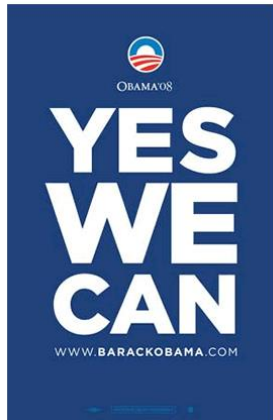
Non linearity increases with the area size

Non linearity is region and precursors dependent

Non linearity increases with the reduction percentage

Conclusion

Can we use source apportionment to design air quality plans ?



BUT WG4 recommend a linearity check before usage



ευχαριστώ πολύ