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Joint Research Centre

WG3 intercomparison: main outcomes and implications for future SA applications

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WG3 Intercomparison Contributors

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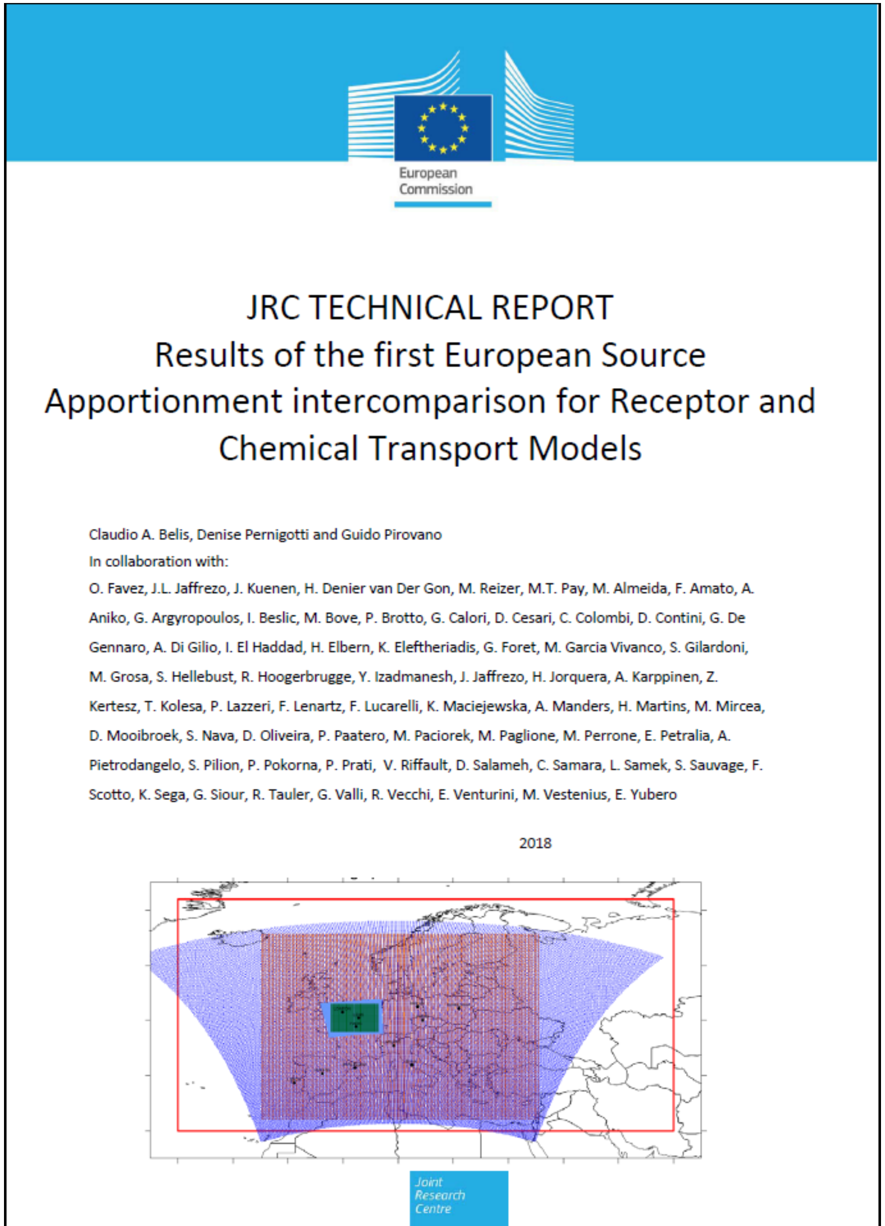
WG3 Intercomparison


JRC TECHNICAL REPORT
Results of the first European Source Apportionment intercomparison for Receptor and Chemical Transport Models

Claudio A. Belis, Denise Pernigotti and Guido Pirovano
In collaboration with:
O. Favez, J.L. Jaffrezo, J. Kuenen, H. Denier van Der Gon, M. Reizer, M.T. Pay, M. Almeida, F. Amato, A. Aniko, G. Argyropoulos, I. Beslic, M. Bove, P. Brotto, G. Calori, D. Cesari, C. Colombi, D. Contini, G. De Gennaro, A. Di Gilio, I. El Haddad, H. Elbern, K. Eleftheriadis, G. Foret, M. Garcia Vivanco, S. Gilardoni, M. Grosa, S. Hellebust, R. Hoogerbrugge, Y. Izadmanesh, J. Jaffrezo, H. Jorquera, A. Karppinen, Z. Kertesz, T. Kolesa, P. Lazzeri, F. Lenartz, F. Lucarelli, K. Maciejewska, A. Manders, H. Martins, M. Mircea, D. Mooibroek, S. Nava, D. Oliveira, P. Paatero, M. Paciorek, M. Paglione, M. Perrone, E. Petralia, A. Pietrodangelo, S. Pilion, P. Pokorna, P. Prati, V. Riffault, D. Salameh, C. Samara, L. Samek, S. Sauvage, F. Scotto, K. Sega, G. Siour, R. Tauler, G. Valli, R. Vecchi, E. Venturini, M. Vestenius, E. Yubero

2018

70 experts involved!

Unprecedented dataset of source contribution estimates from RMs and CTMs

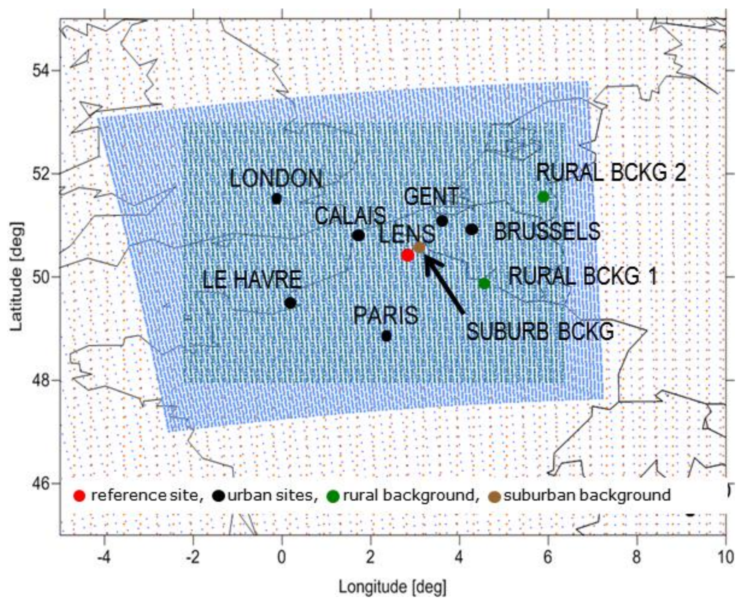
One of the largest SA exercises in the world

The findings deriving from this exercise will impact the way in which source apportionment is carried out and interpreted

The final report already revised by co-authors is complete

It is now being processed to be published as a JRC Technical report and will be distributed on the Fairmode website

Intercomparison outline – Source oriented models (CTM)



MULTI SITE

CTM

Performance tests:

Z-scores

RMSEu

SINGLE SITE

RM – CTM

Performance tests:

Z-scores

RMSEu

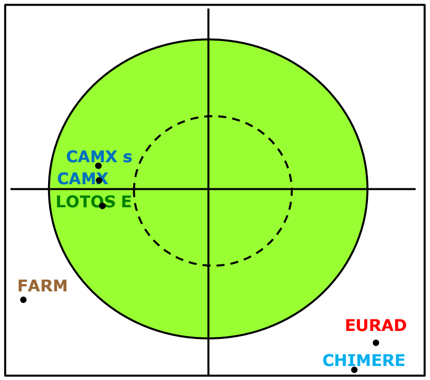
id	model	method	MANDATORY	OPTIONAL
cA	CAMx	CTM	selected for reference	
cAo	CAMx	CTM		selected for reference
cAs	CAMx	CTM	sensitivity run	sensitivity run
cAso	CAMx	CTM	sensitivity run	sensitivity run
cAs2	CAMx	CTM	sensitivity run	sensitivity run
cB	FARM	CTM	selected for reference*	
cBo	FARM	CTM		selected for reference*
cD	LOTOS	CTM	selected for reference	
cDo	LOTOS	CTM		selected for reference
cE	EURAD	CTM	selected for reference*	
cF	CHIMERE	CTM	NH_4 and NO_3 not reported	NH_4 and NO_3 not reported

Mandatory: all participants, few sources (8)

Optional: many sources (14), few participants

The source chemical profiles: the case of Agriculture

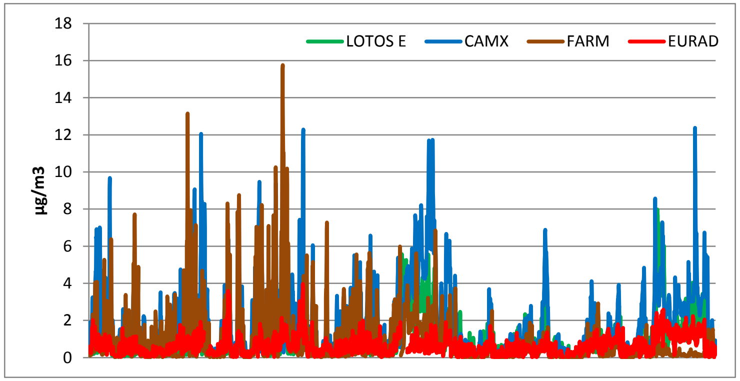
Performance of CTMs for Agriculture



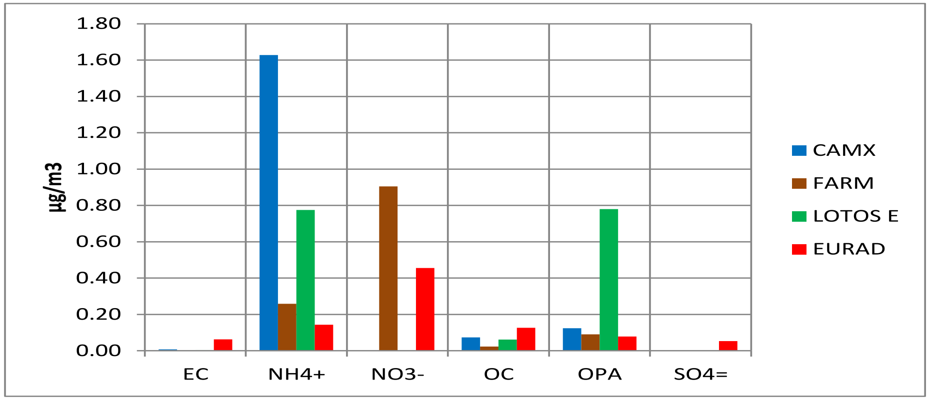
whole period	LOTOS E	CAMX	FARM	EURAD	CHIMERE
average (µg/m3)	0.91	1.78	0.95	0.64	0.04
sd (µg/m3)	1.09	1.87	1.51	0.49	0.06

R	LOTOS E	CAMX	FARM	EURAD	CHIMERE
LOTOS E	1	0.60	0.26	0.50	0.37
CAMX	0.60	1	0.42	0.52	0.49
FARM	0.26	0.42	1	0.27	0.24
EURAD	0.50	0.52	0.27	1	0.25
CHIMERE	0.37	0.49	0.24	0.25	1

Time trends for Agriculture



Chemical profiles for Agriculture



-Both methods model secondary PM properly but their objectives are different

-To what extent are tagged species and brute force comparable?

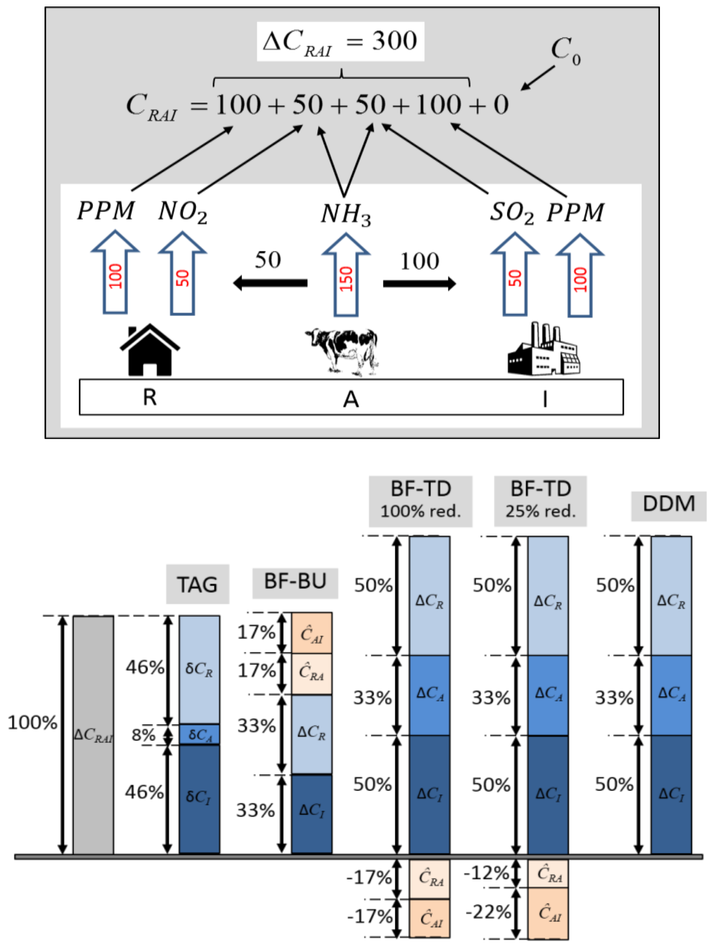
Different CTM SA approaches

SIMILAR SLIDE OF UTRECHT PLENARY 2017

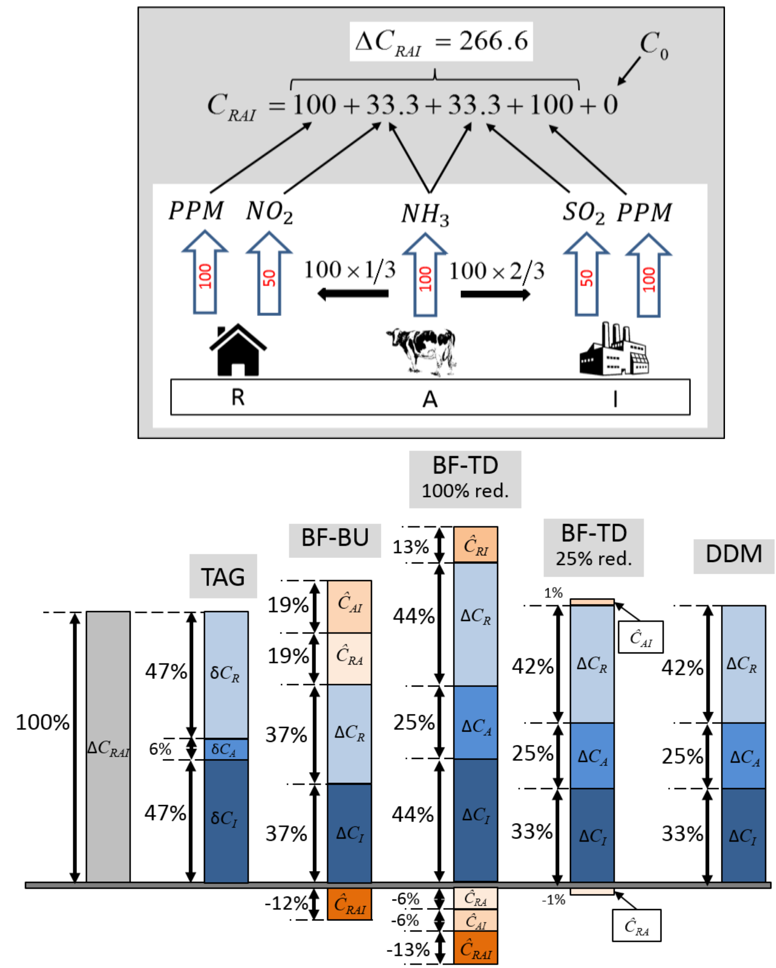
	Tagged Species	Brute force TD (no interaction)
Description	Tagged species are used to track the contributions of sources in every grid cell by mass balance. Conc. = (emission+ import+ formation) – (export+ degradation+ deposition)	Estimate the contribution of sources by comparing the BC with a run where the source of interest has been reduced by a given % over the whole domain.
Kind of approach	Static Depicts the situation corresponding to the input dataset	Dynamic It is actually is a sensitivity analysis. Estimations are obtained by introducing changes in the emissions to make inferences for alternative situations.
Underlying question	What is the actual mass transferred from a source to a pollutant concentration in the studied area/time window?	What would be the reduction in concentrations corresponding to a given reduction in emissions?
Runs	Accomplishes the apportionment in one single run	Requires a number of runs equal to the number of sources to apportion plus base case
Mass conservation	The sum of the contributions of the sources equal to the total mass (concentration) of the apportioned pollutant (by definition)	The total mass of the different sources is obtained from independent runs. The sum of the masses of the sources may not be equal to the pollutant mass in the base case. Post processing may be need to re-normalize the sources.
Advantages	Reflects the actual situation of the used dataset. Provides absolute and relative estimations	Respond to the question of interest for the policy maker. Can be used for planning
Disadvantages	The actual contribution of a source may not provide information about the behaviour of that source in other situations	Requires many runs

Source Apportionment and sensitivity analysis

Case 1: interactions



Case 2: interactions and limited regime



Strong non-linearity is associated to secondary pollutants deriving from precursors emitted by different sources.

We need to understand how often (when, which ones) sources stray from linearity

Clappier et al., 2017

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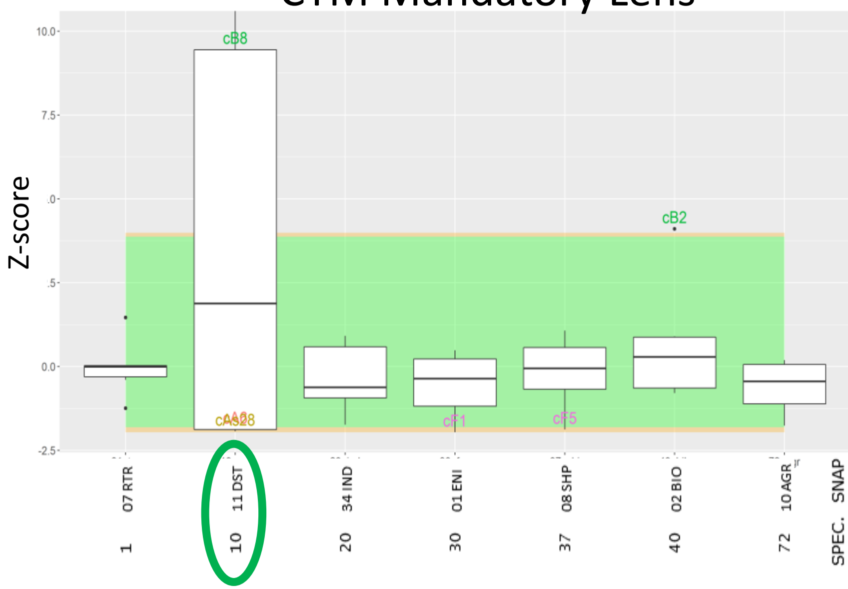
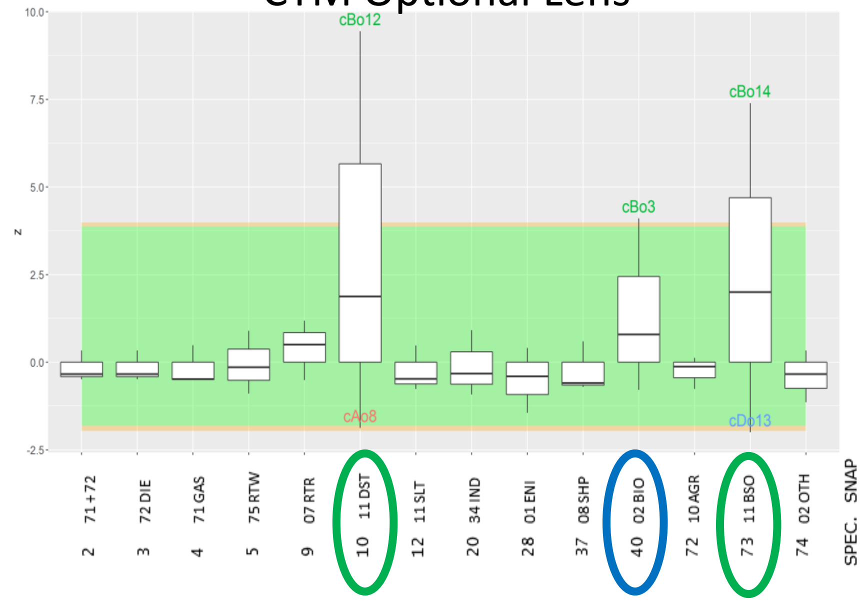
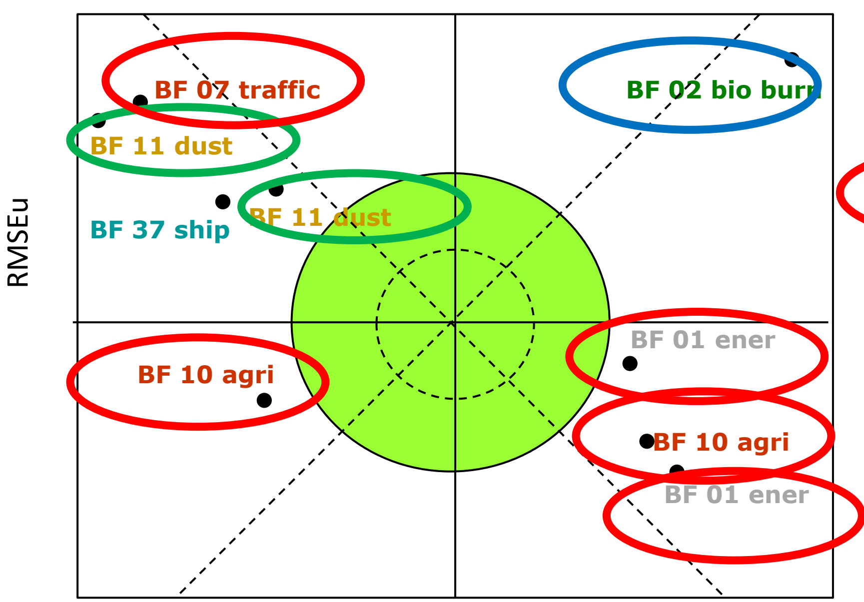
ONLY TAGGED SPECIES RESULTS IN THE REFERENCE

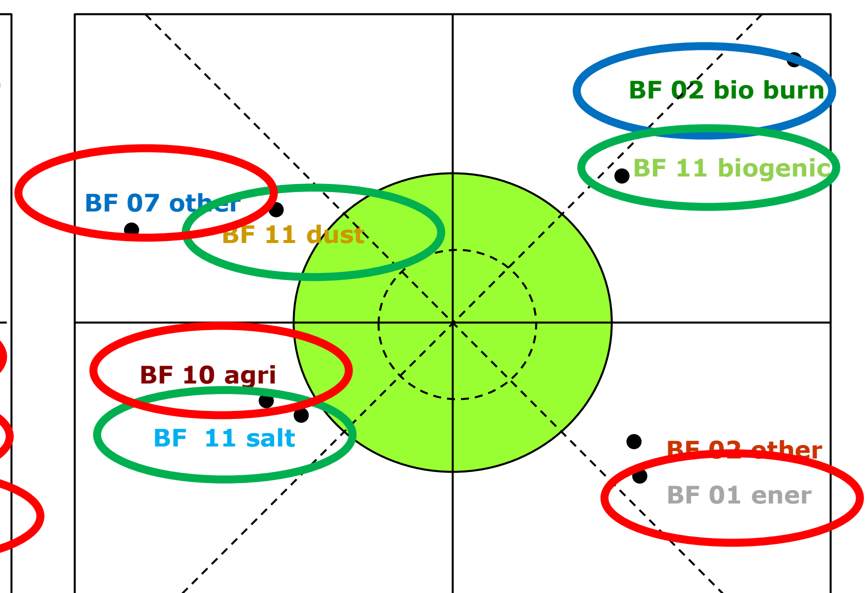
CTM Mandatory Lens



CTM Optional Lens





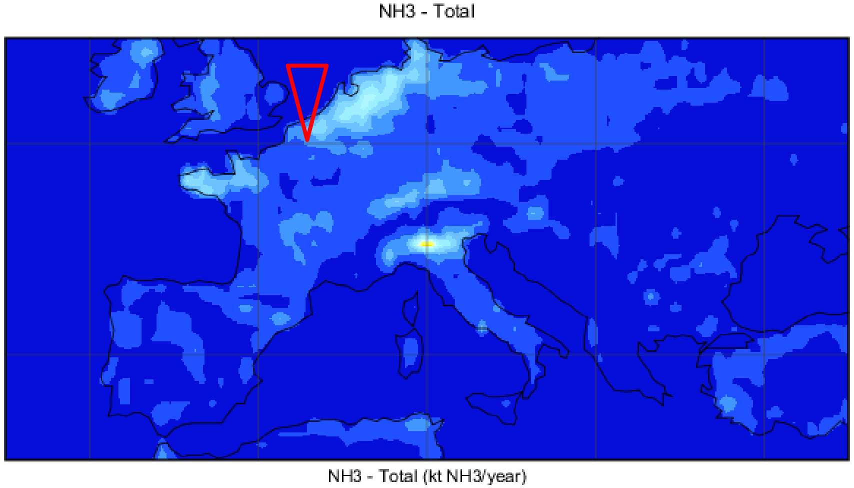


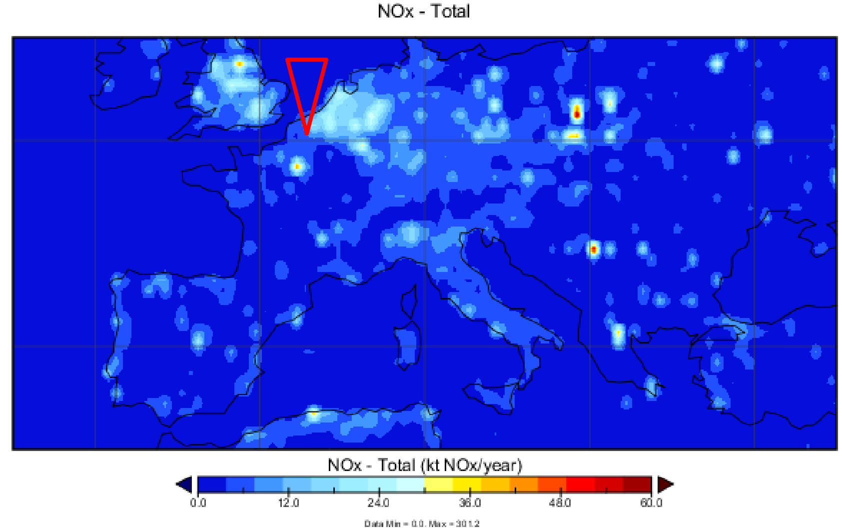
different model parameterization

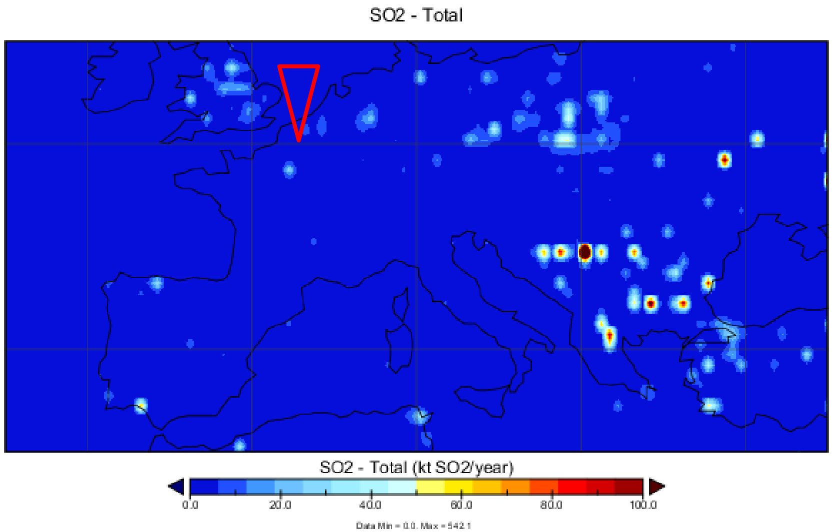
Non linear secondary processes

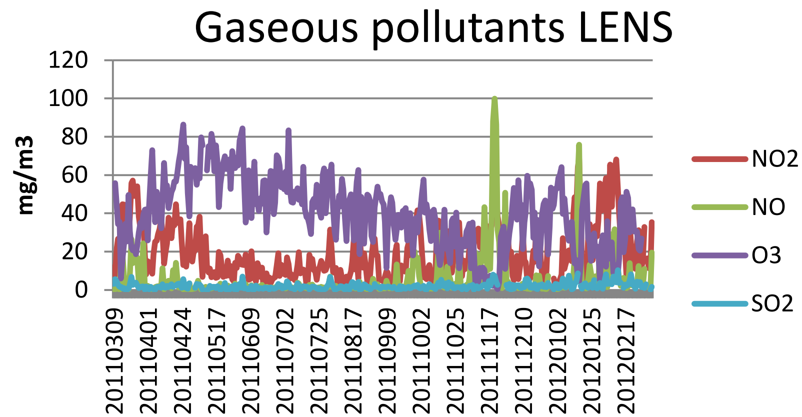
Both non linear and diff. parameterization

Emissions fields ECLIPSE 2010









BF relatively high estimations of Traffic, domestic heating and (NOx emitting sources) and low estimations of Agriculture and Energy production (NH3, SO2) suggest a NO2 limited regime. Because changes in NO2 emissions determine higher changes in concentrations than changes in NH3 or SO2.

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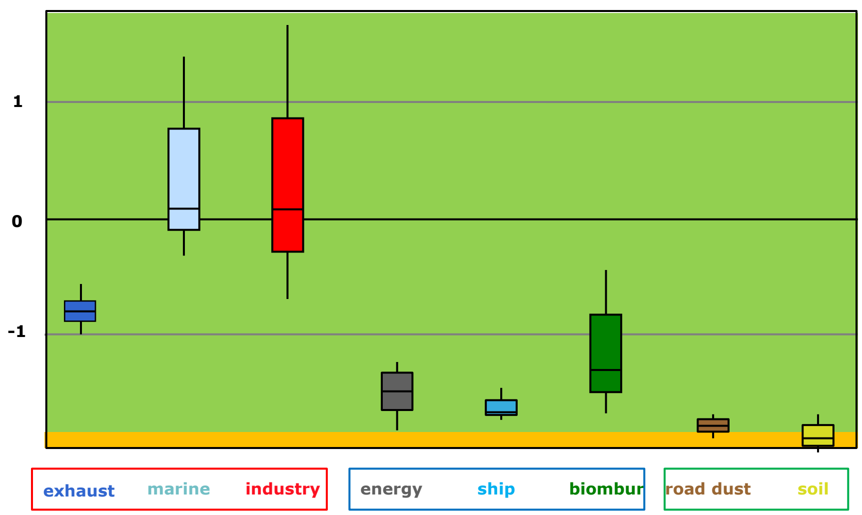
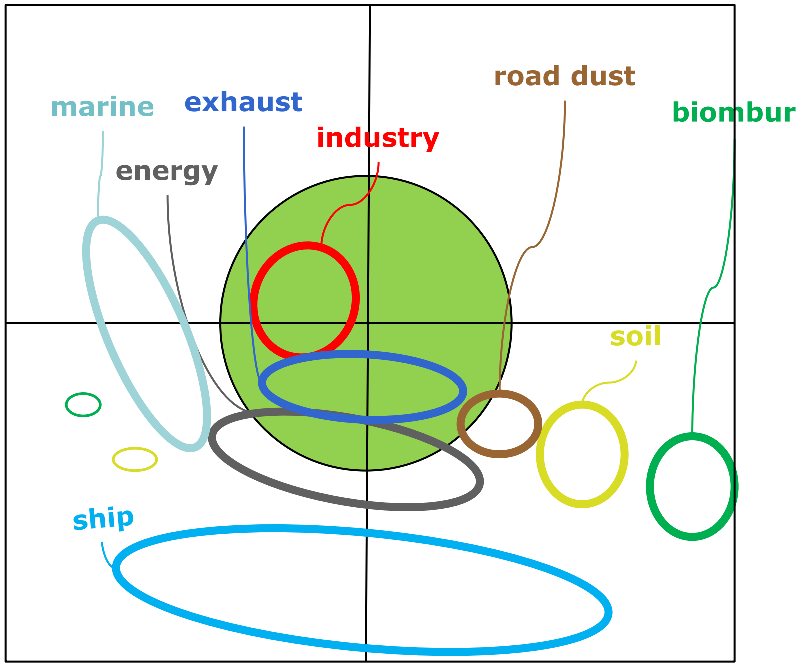
CTMs vs RMs Lens

z-score (overall average)



Target plot (time series)



The comparability between RMs and CTMs varies among sources

Conclusions of the IE (CTM)

- The intercomparison made it possible to cross validate CTMs among each other and with RMs.
- The performance of the SA applications was evaluated and an estimation of the uncertainties (repeatability) was obtained.
- The analysis of CTM source chemical profiles was useful to understand the different modelling approaches used when executing SA applications
- When using tagged species as reference, differences between tagged species and brute force are mainly observed in secondary processes involving precursors from different sources (agriculture, power plants, traffic, biomass burning).
- The lessons learned in the intercomparison are been incorporated in the WG3 technical guide on SA model applications.
- More work is needed to delimit the conditions under which TS and BF are comparable.

Introducing a new terminology to better clarify similar concepts

Source apportionment and Scenario Analysis are similar concepts but there are subtle differences because they have different objectives

Where the confusion comes from?
Very often (linear conditions) contributions and impacts are numerically the same. In the past there was little understanding on the implications of these differences for the SA results.

Source apportionment

Aims at computing **contributions** : mass transferred from sources to concentrations.

The mass is conserved. The sum of the parts (sources) is equal to the total (PM mass)

It is designed to investigate the role of sources in a given dataset

Scenario analysis/ brute force

Computes the change in concentrations due to a change in emissions. We propose to call this **impact**

is primary designed to explore situations different than the one used to create it → planning

It is necessary to bear in mind that extrapolating from one dataset to another (future or alternative) implies an additional degree of uncertainty

Source allocation

It is a specific case of scenario analysis where the **impacts** are calculated for all sources and their sum is coherent with the mass of the total pollutant.

Even if they sum up to 100% the output of this technique matches the definition of impact and not the one of contribution

What to do?

- To promote proper use and interpretation of results , it is important to define an appropriate terminology.
- To specify the cases where contribution ≠impact: strong non linearity (typically secondary pollutants deriving from precursors emitted by different sources)
- To delimitate the overlapping area between SoAp and Sc An : in this case contribution can be used for planning and impacts for source apportionment

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Is Source apportionment needed/useful to fulfill AQD Annex XV?

*" 5) **Origin of pollution** (a) list of the main emission sources <u>responsible</u> for pollution, …, and c) information on pollution imported from other regions"*

*"6) **Analysis of the situation** a) details of those factors <u>responsible</u> for the exceedance (transport (advection), formation of secondary pollutants)"*

Source Apportionment applications:

1. SA tools are robust (both RM and CTM) and are the most suitable to estimate the mass transferred from sources to concentrations for a known dataset (area, time window) and therefore to identify and quantify the contributions during an exceedance (smoking gun).

2. Identify the source contributing to pollution present in an area to be further analysed by scenario analysis tools (focus scenarios on the relevant sources) for planning purposes. (APPRAISAL, Viaene et al., 2016). But for non linear sources the computed contributions should not be used directly for planning.

3. For pollutants with linear or near-linear behaviour source apportionment contributions can be considered as impacts and used directly for planning

4. Transfer of mass from sources to concentrations (contributions) are necessary to study the impact of pollutants on health

5. Source apportionment (RM) is able to detected sources or processes that are not well described in the emission inventories and, therefore, contributes to their improvement by pointing out gaps (e.g. biomass burning, organics).

6. Source apportionment (SM TS) can be validated by comparison with RM

7. Source apportionment is also needed to validate the models that are used to develop SOURCE RECEPTOR RELATIONSHIPS (e.g. for linear sources)

8. Comparing source apportionment carried out before and after a measure can be used to assess its effectiveness a posteriori (also for secondary) (Gianini et al., 2012, Diapouli et al., 2017, Pandolfi et al. 2016, Lee et al., 2010)

Example of assessing abatement measures using Source Apportionment

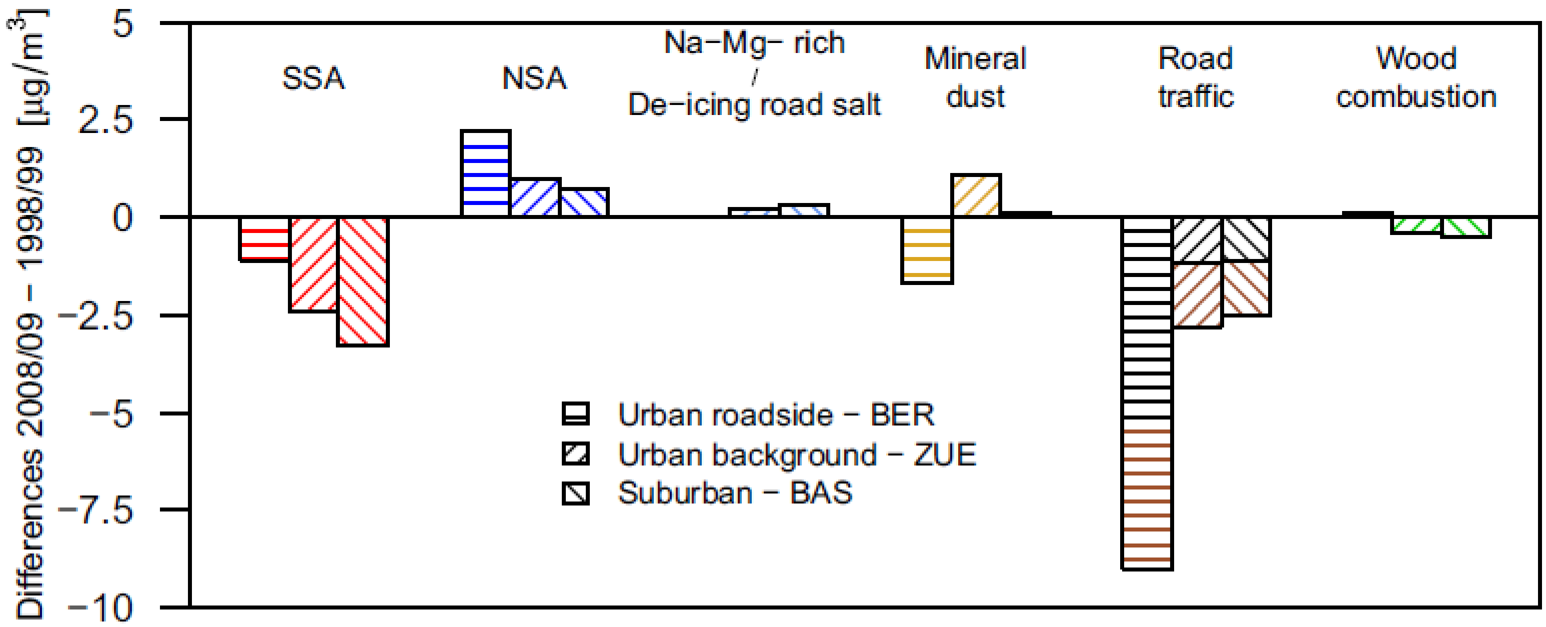

Fig. 7. Evolution of source contributions between 1998/1999 and 2008/2009 for the urban roadside site BER, urban background site ZUE and for the suburban site BAS.

"This indicates that the measures implemented in Switzerland and in neighbouring countries to reduce emissions of sulphur dioxide and PM10 from road traffic were successful."

M.F.D. Gianini et al. / Atmospheric Environment 54 (2012) 149-158

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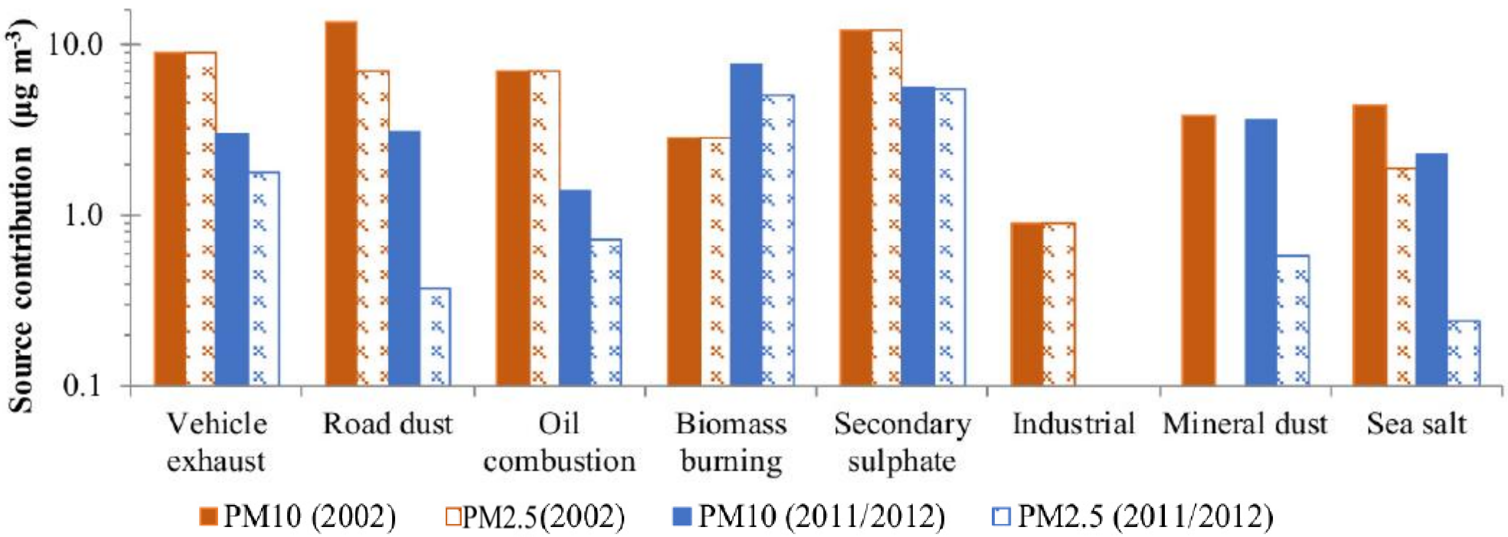
Example of assessing abatement measures using Source Apportionment (2)



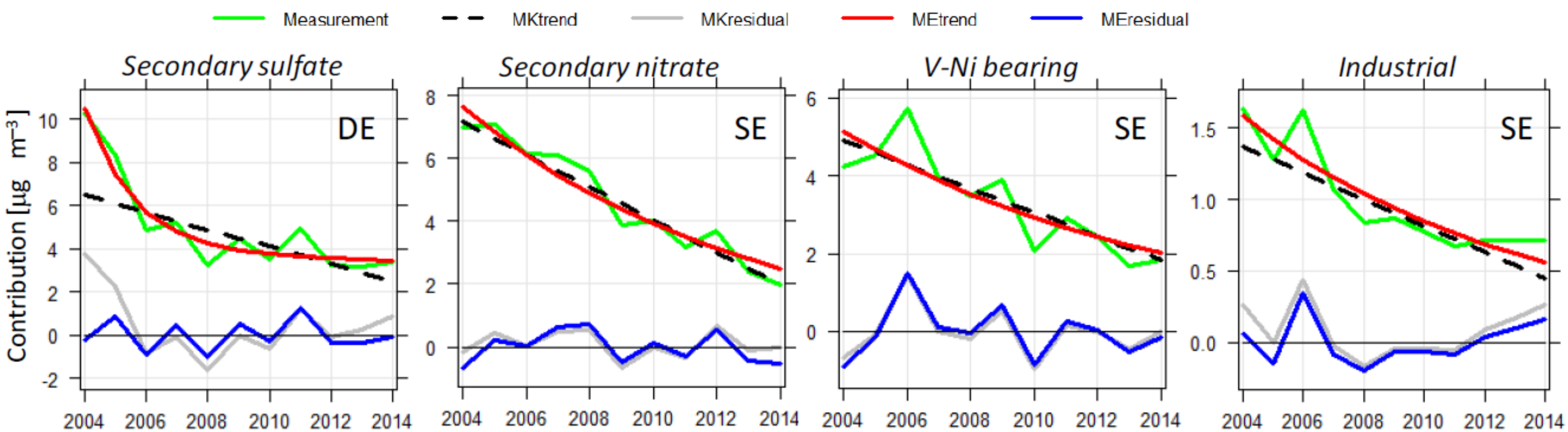
Mean changes in source contributions to PM (PM10 and PM2.5) in the city of Athens, Between 2002 and 2011-2012.

"The change in source contributions over 10 years clearly demonstrates the effective reduction in emissions due to control measures and technological development"

"…it also reflects the effects of the financial crisis in Greece during these years, which has led to the adoption of more polluting practices (biomass burning) by the local population in an effort to reduce living costs."

E. Diapouli et al. Atmospheric Environment 164 (2017) 416-430

Example of assessing abatement measures using Source Apportionment (3)



Mann–Kendall and multi-exponential trends for source contributions in PM10 at Barcelona.

Measured concentration (green line); multi-exponential trend (red line); multi-exponential residuals (blue line); Mann–Kendall trend (black line); Mann–Kendall residuals (gray line).

"The different types of trends observed reflected the different effectiveness and/or time of implementation of the measures taken to reduce the concentrations of atmospheric pollutants. "

"Moreover, the trends of the contributions of specific sources such as those related with industrial activities and with primary energy consumption mirrored the effect of the financial crisis in Spain from 2008."

Pandolfi et al. Atmos. Chem. Phys., 16, 11787–11805, 2016

SOURCE APP. AND PLANNING IN THE CONTEXT OF THE AQ MANAGEMENT

ACTIVTY: SOURCE APPORTIONMENT

TOOLS: CTM TS, RMs, SMs

OUTPUT: CONTRIBUTIONS

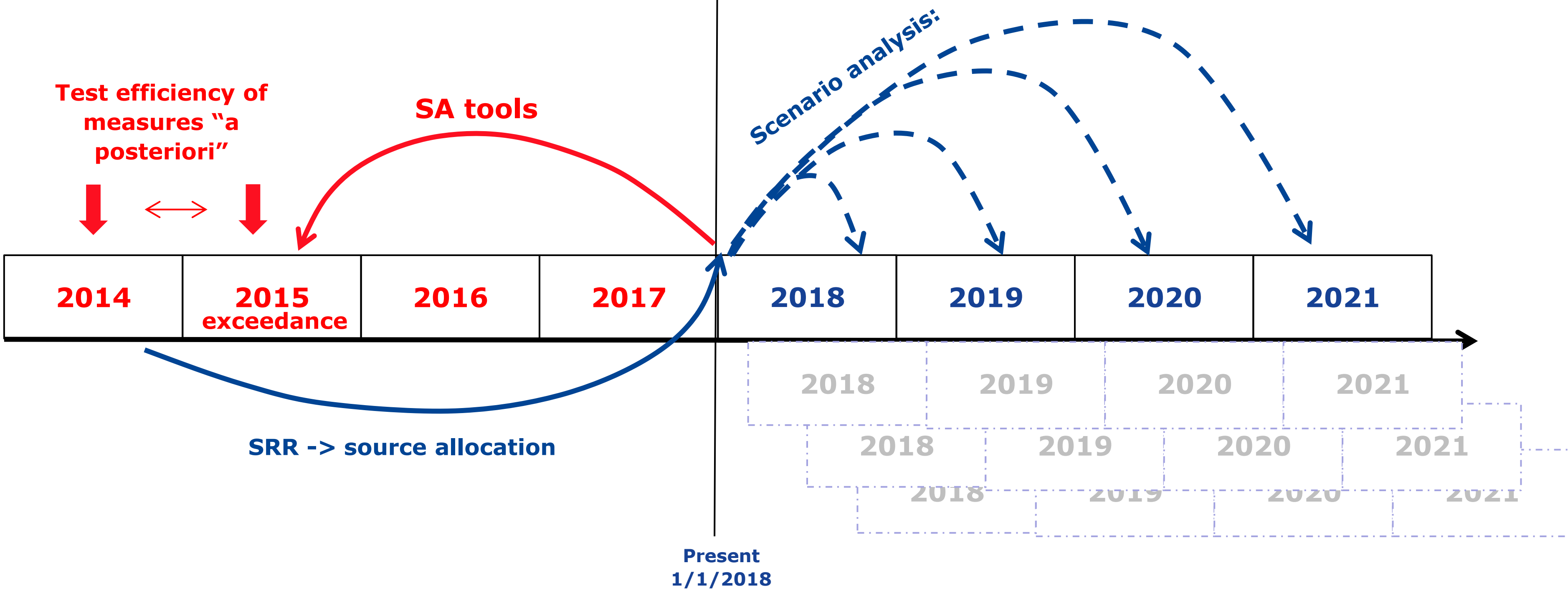
IPR: DATA FLOW I

ACITIVITY:PLANNING

TOOLS: SCENARIO ANALYSIS, CTM BF, SOURCE ALLOCATION

OUTPUT: IMPACT

IPR: DATA FLOW J



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Thank you for your attention