

The SHERPA approach

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SHERPA
Screening for High Emission
Reduction Potential on Air



Input data provided by INERIS



Software developed by TerrAria
under the Contract Procedure
no. JRC/IPR/2014/H.2/0023/NC

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Palmanova, Aprile 2017



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Motivations



Screening for High Emission Reduction Potentials on Air quality

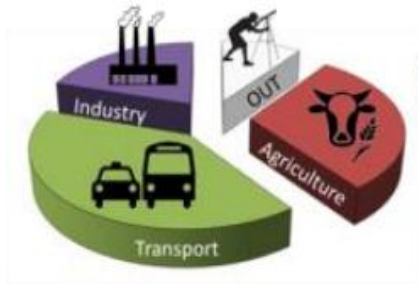


WHAT can I influence?
WHICH sectors/pollutants?

WITH WHOM should I
coordinate actions?

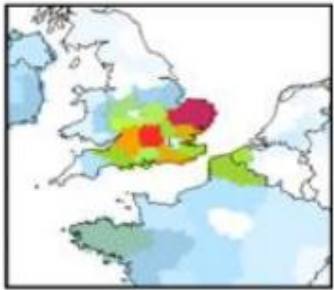
HOW MUCH impacts?

Tasks



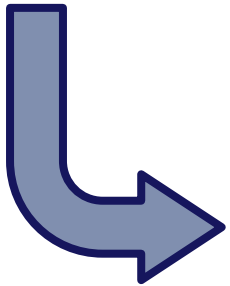
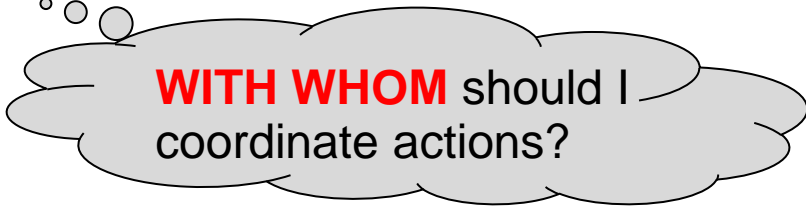
Source allocation

Computes the relative contribution of the various emission sectors/precursors originating inside a region to the amount of pollution in the area



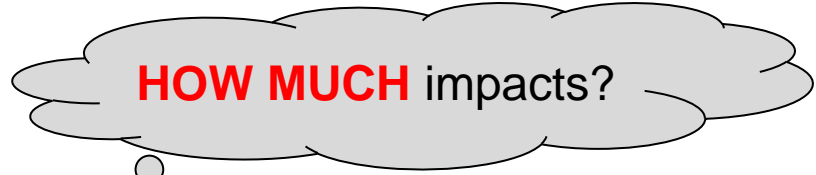
Governance

Identifies the principal source areas of the pollution at a location



Impacts

Tests the impact of an emission reduction scenario in a region





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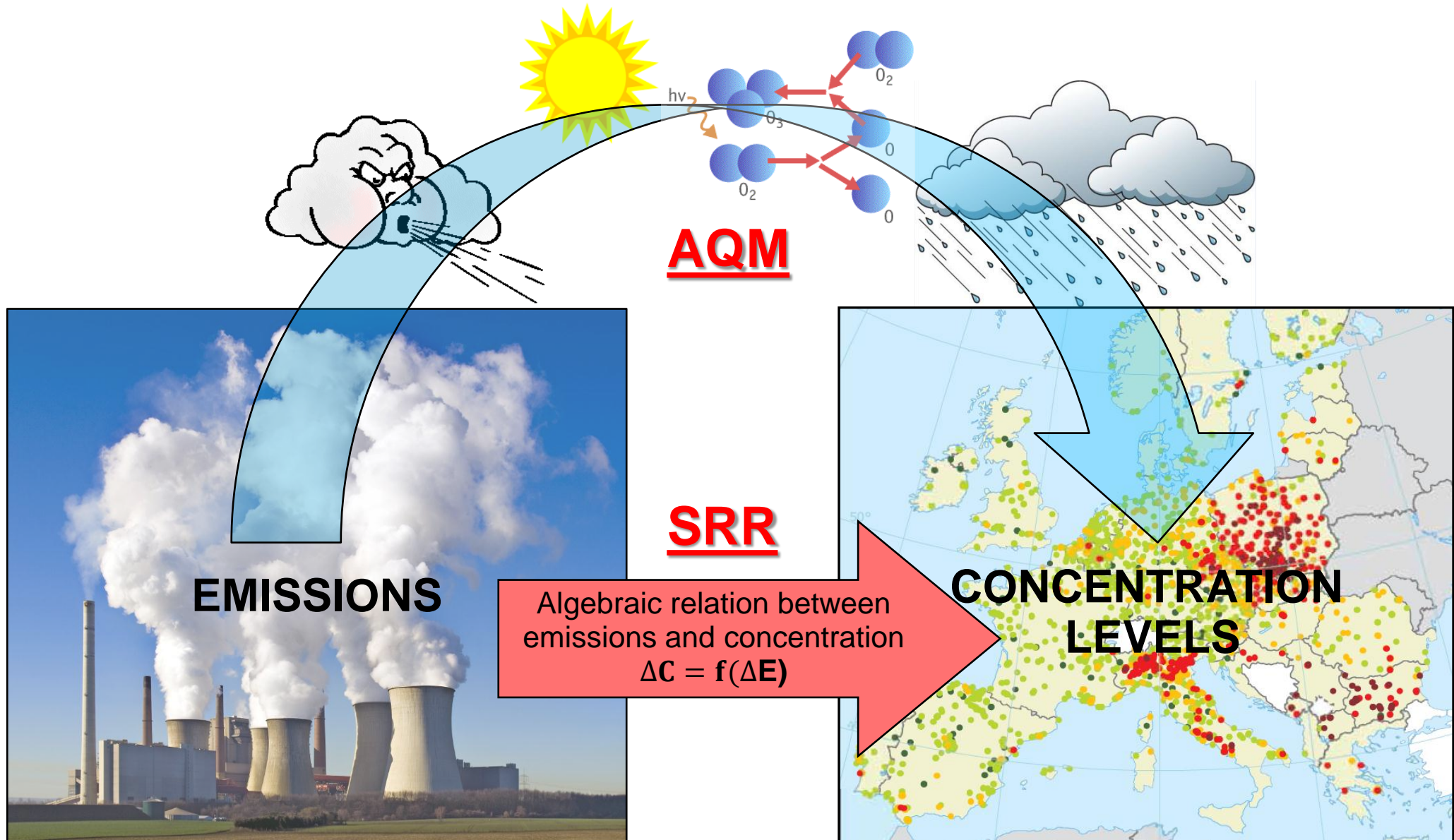
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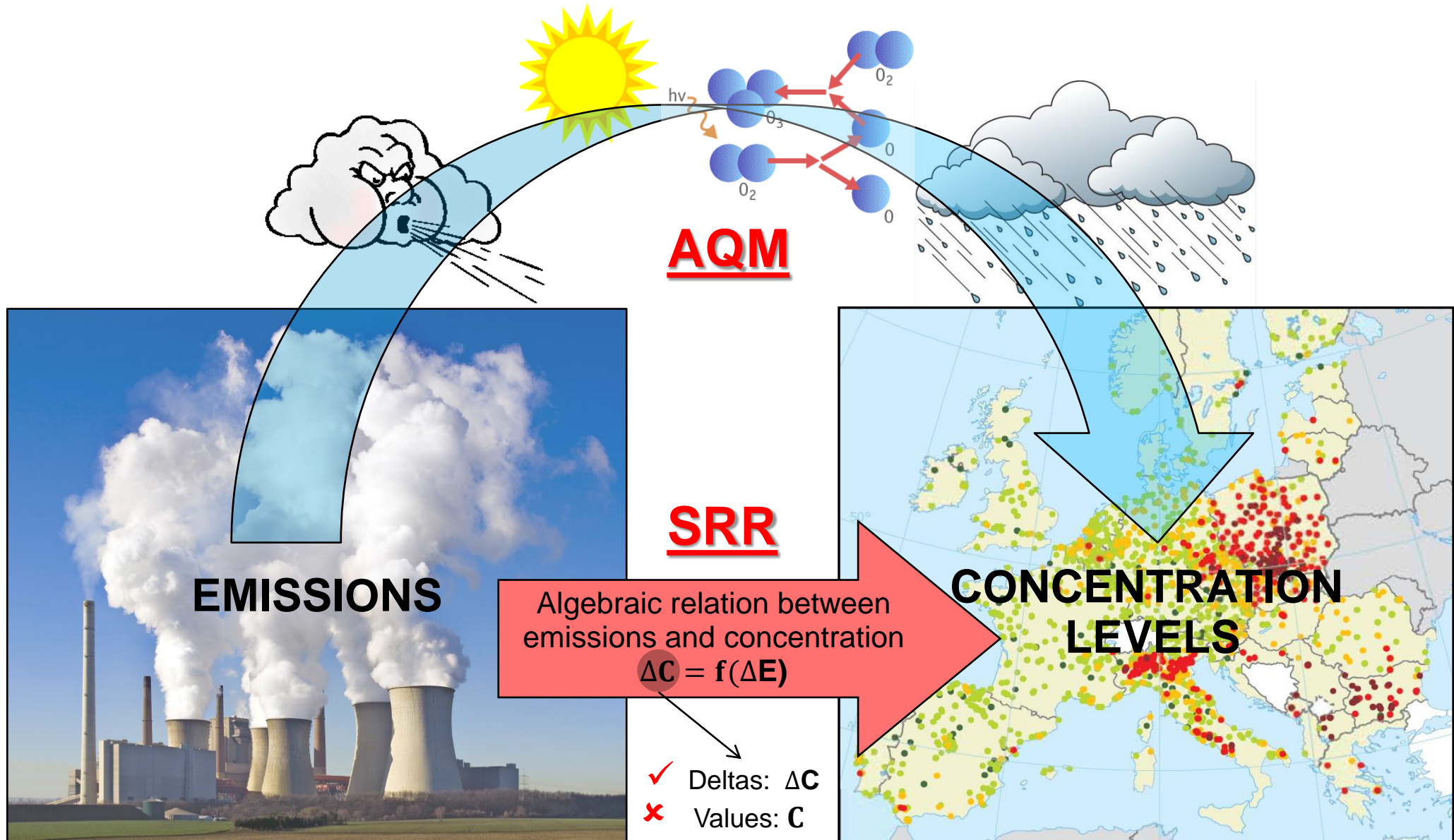
Source Receptor Relationships (SRR)

The goal of the SRR is to mimic an AQM to calculate as quickly as possible the effect of emission reductions on concentration levels



Source Receptor Relationships (SRR)

The goal of the SRR is to mimic an AQM to calculate as quickly as possible the effect of emission reductions on concentration levels



AQM - SRR

AQM (Integrated **A**ssessment **M**odeling frame)

- ✓ High accuracy
- ✓ High temporal resolution
- ✓ High spatial resolution
- ✗ Long calculation time (hours for 1yr simulations)
- ✗ Interactivity not allowed



SRR (SHERPA, GAINS, AERIS, RIAT+)



- ✓ **Speed** (minutes for 1yr simulations)
- ✓ Robustness
- ✓ User friendly
- ✓ Interactivity

SRR ensures a **good compromise among speed and accuracy**: relative bias (compared to the AQM) less than 10%



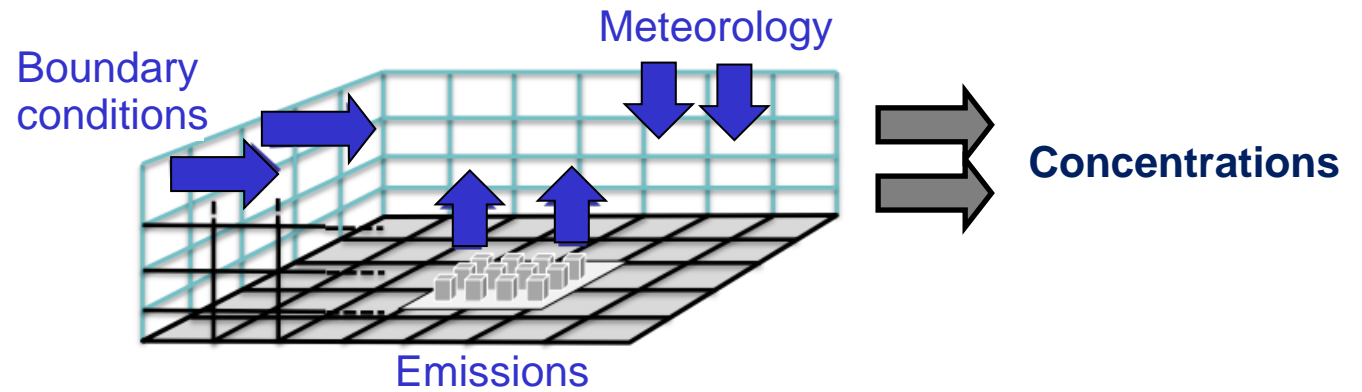
SRR Methodology

0) Base case

- Meteorology
- Emissions



1) Full Air Quality Model simulations



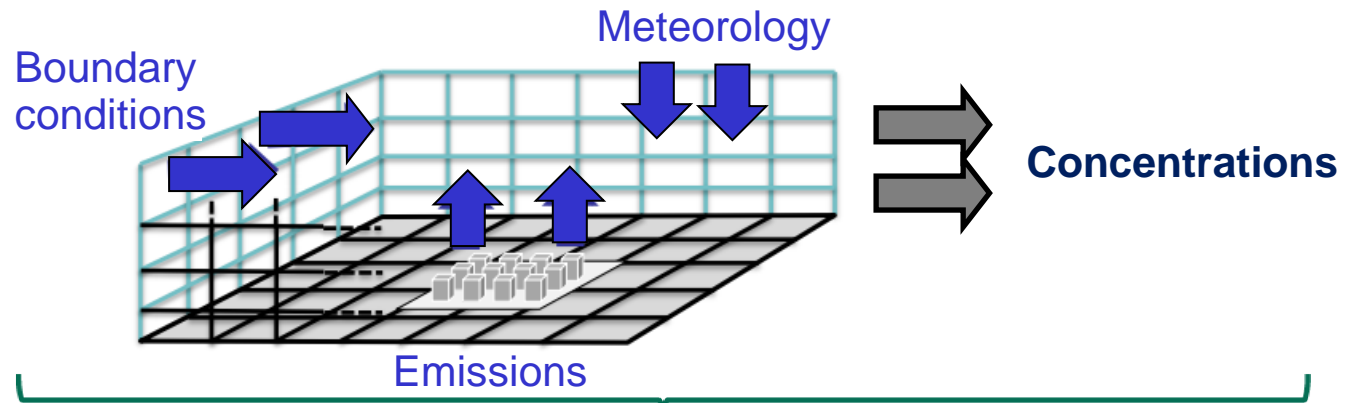
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0) Base case

- Meteorology
- Emissions



1) Full Air Quality Model simulations



2) Training phase

Algebraic relation between
gridded emission and
concentration deltas

$$\Delta C_j = f_j(\Delta E_1, \dots, \Delta E_i, \dots, \Delta E_n)$$

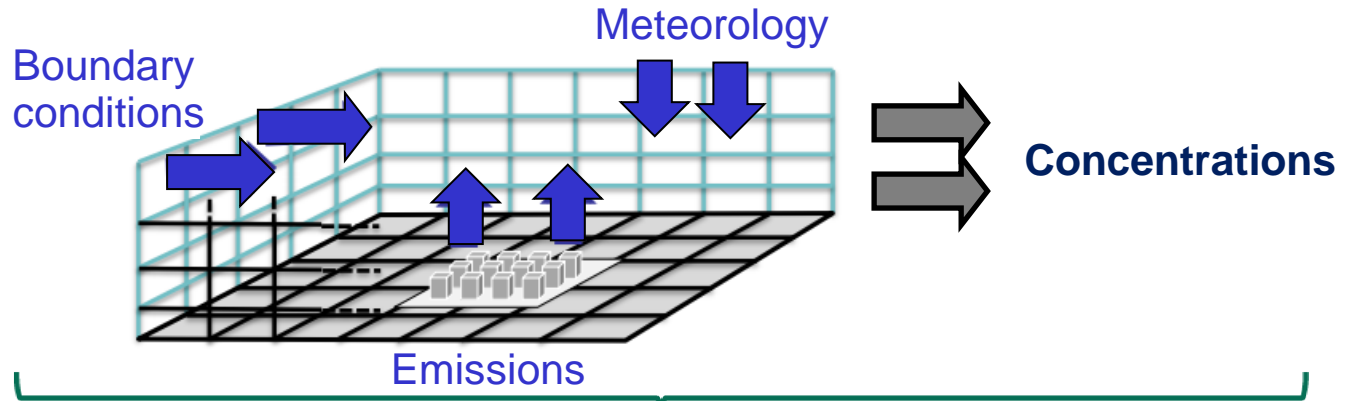
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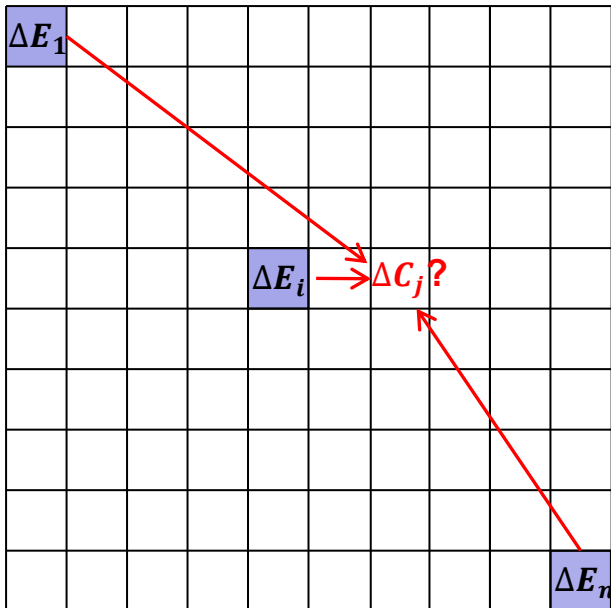


1) Full Air Quality Model simulations



2) Training phase

Emission reductions

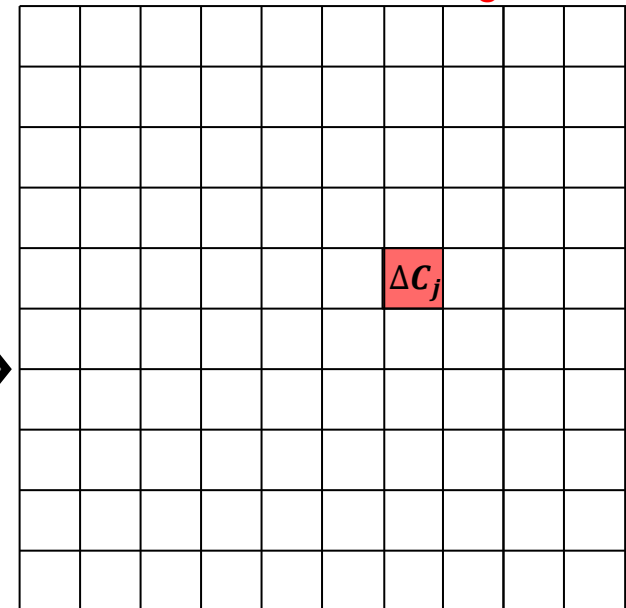


3) Source Receptor relationship simulations

Algebraic relation between gridded emission and concentration deltas

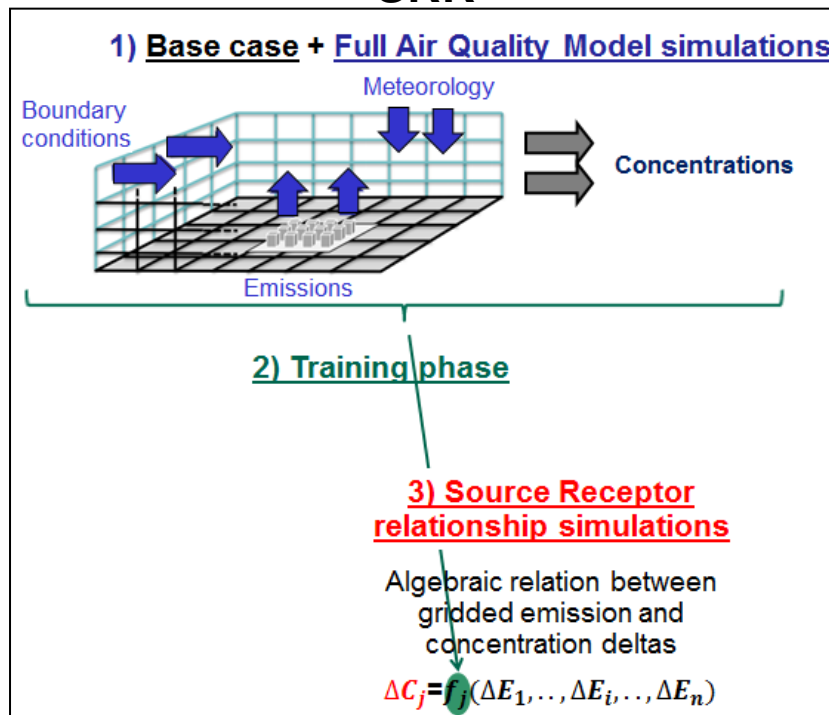
$$\Delta C_j = f_j(\Delta E_1, \dots, \Delta E_i, \dots, \Delta E_n)$$

Concentration changes

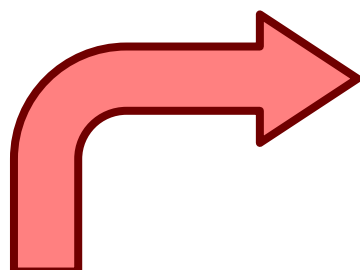
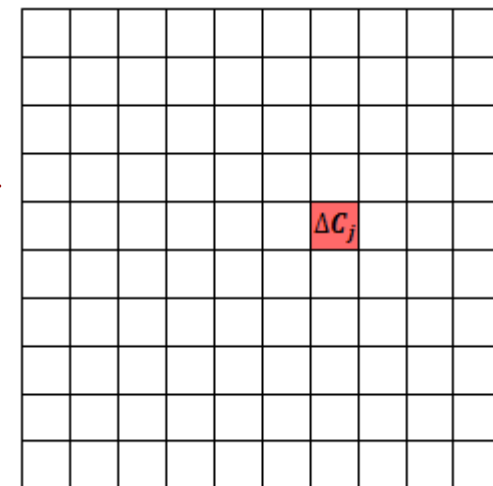


SRR Validation

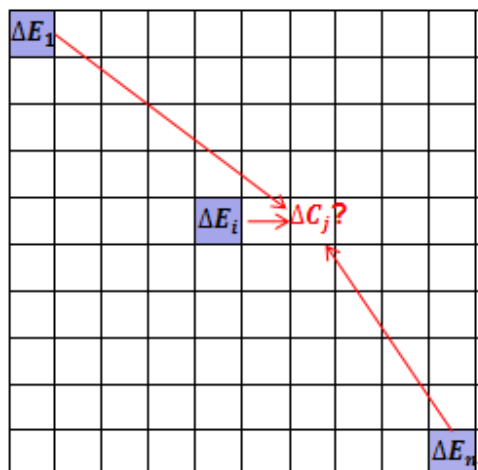
SRR



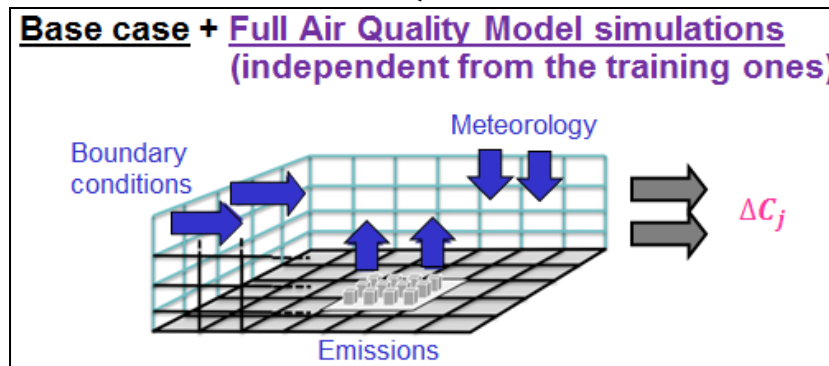
Concentration changes



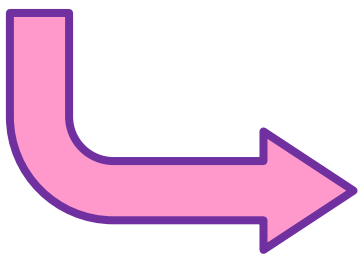
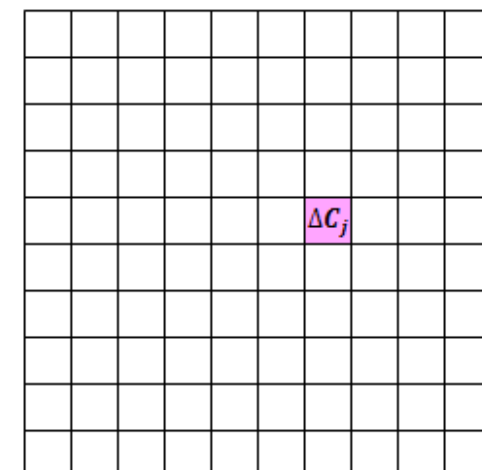
Emission reductions



AQMs

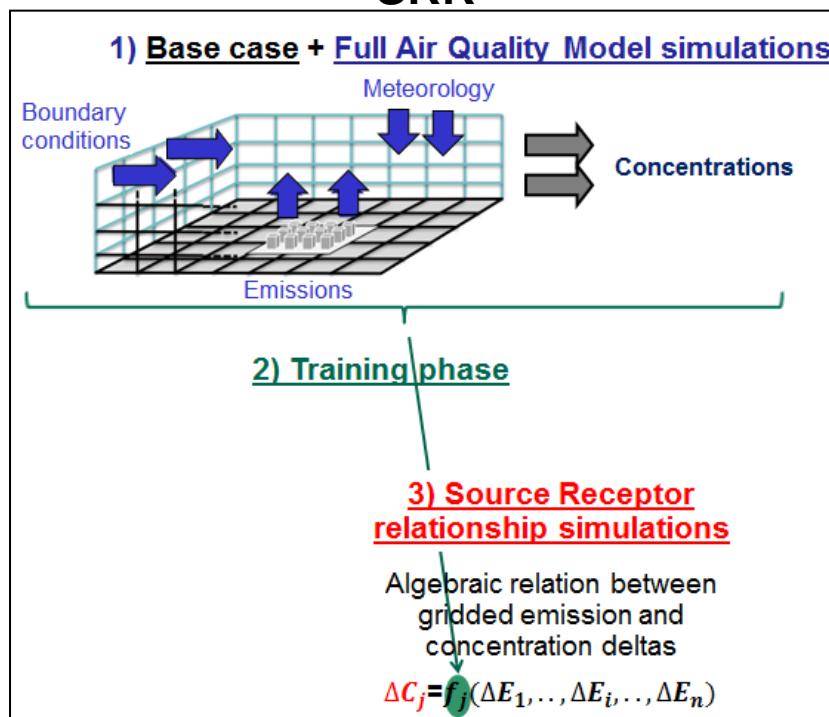


Concentration changes

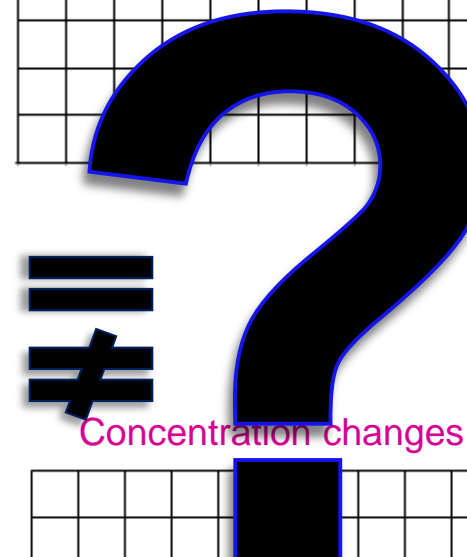
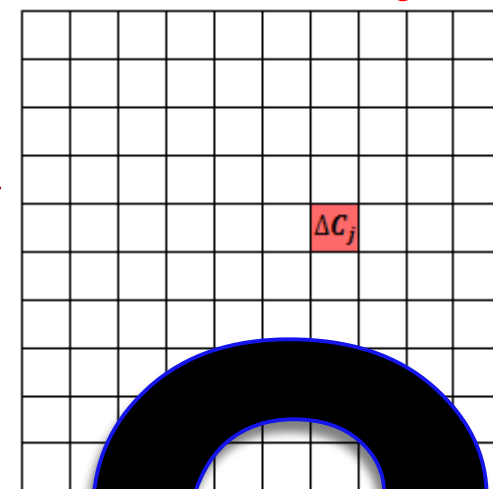


SRR Validation

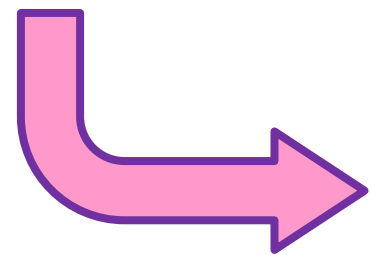
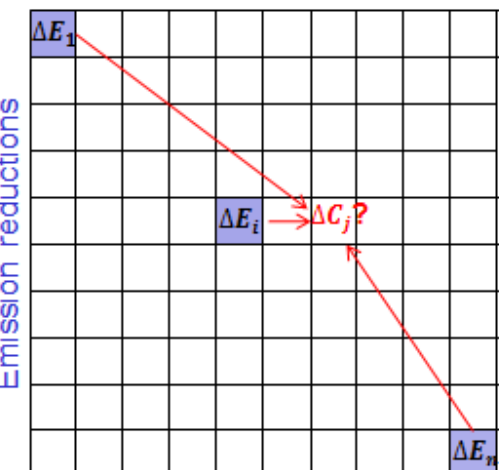
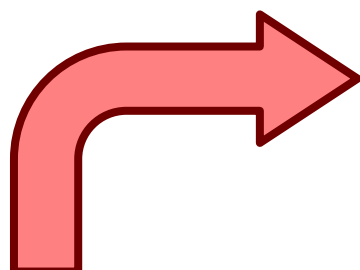
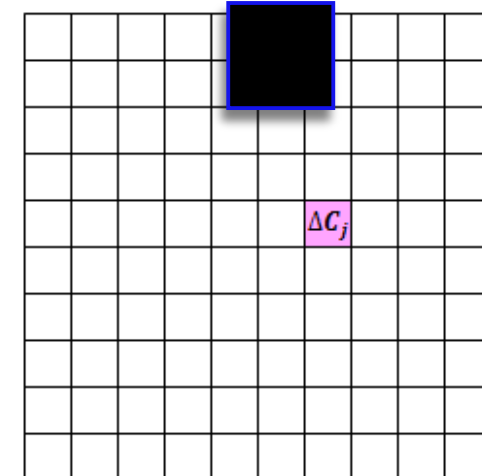
SRR



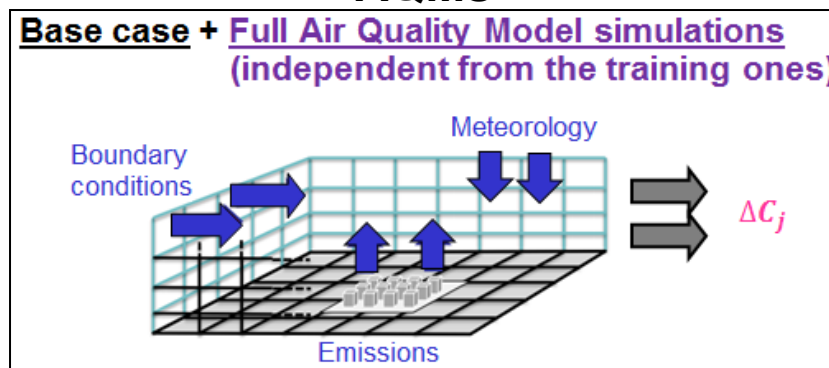
Concentration changes



Concentration changes



AQMs





SRR characteristics

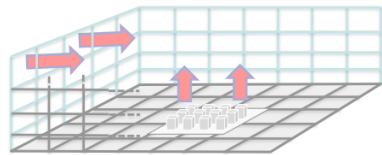


- ✓ **Speed**
- ✓ **Spatial flexibility**
- ✓ **Light set-up**
- ✓ **Robustness**
- ✓ **Accuracy**

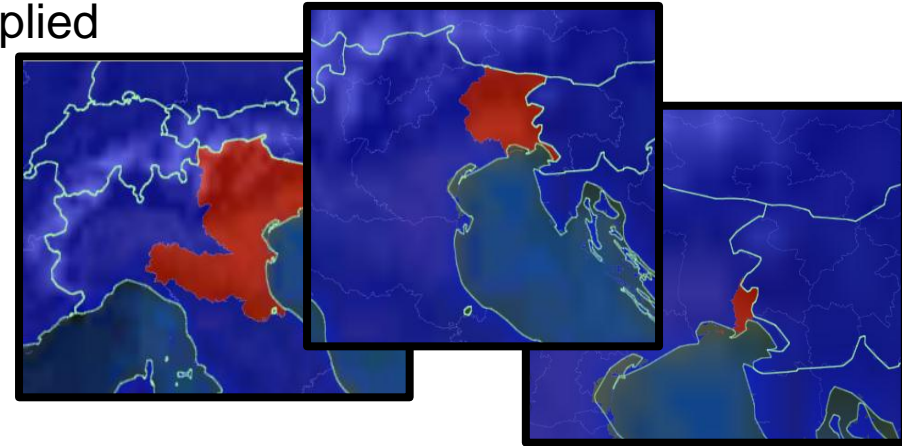
SRR characteristics

- ✓ Speed
- ✓ **Spatial flexibility**
- ✓ **Light set-up**
- ✓ Robustness
- ✓ Accuracy

Limited number of AQM simulations required for training



Freedom in defining the resolution of the areas where emission reductions will be applied

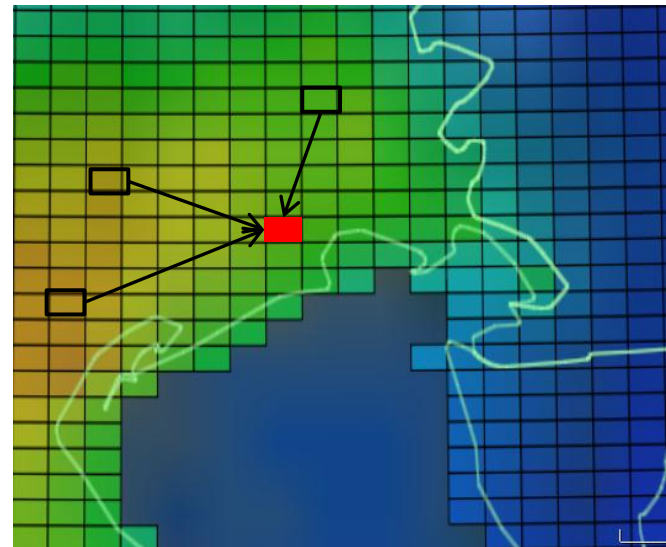


Good comparability between SRR and AQM results (dependence on training AQMs)

Source-aggregations (fixed or sliding)



Cell-to-cell relationships





SRR characteristics



✓ **Speed**

✓ **Spatial flexibility**

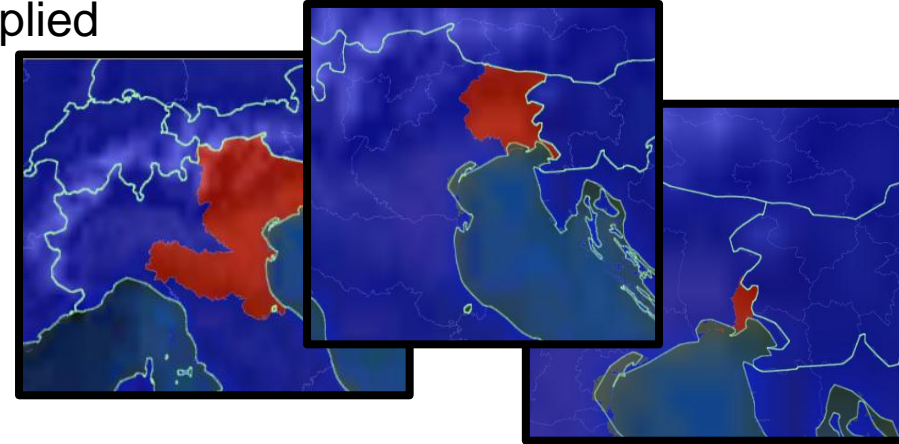
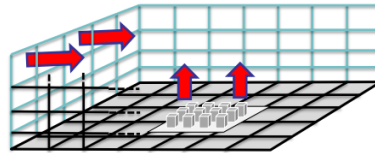
✓ **Light set-up**

✓ **Robustness**

✓ **Accuracy**

Freedom in defining the resolution of the areas where emission reductions will be applied

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SRR characteristics

✓ **Speed**

✓ **Spatial flexibility**

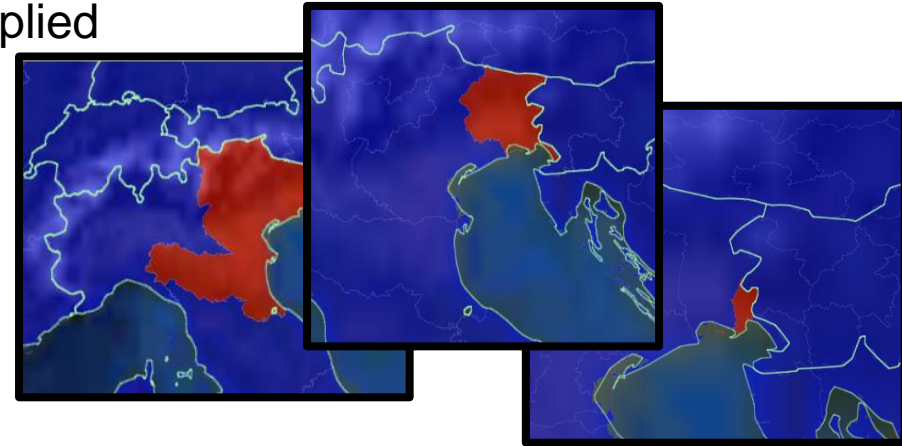
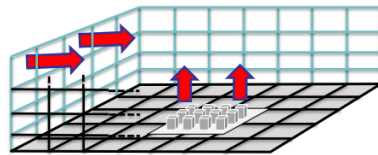
✓ **Light set-up**

✓ **Robustness**

✓ **Accuracy**

Freedom in defining the resolution of the areas where emission reductions will be applied

Limited number of AQM simulations required for training



Good comparability between SRR and AQM results (dependence on training AQMs)

SRR:	Description:	SPEED	SPATIAL FLEXIBILITY	LIGHT SET-UP	ROBUSTNESS
GAINS	S-aggregation in terms of countries Assumes linearity	T	F	T	T
AERIS	S-aggregation in specific sectors	T	F	T	T
RIAT+	S-aggregation in four large quadrants Neural network	T	T	F	T
Multi-ring	sliding S-aggregation (rings) Assumes linearity	T	T	T	F
Bell-shape (SHERPA)	Cell-to-cell relationship distance weighted Assumes linearity	T	T	T	T



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- **Linear Approaches:**
 - **Multi-ring Approach**
 - **Bell-shape Approach (SHERPA)**
- **SHERPA Algorithm**

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SHERPA characteristics



- ✓ **Speed** < 5 min
- ✓ **Spatial flexibility** High (cell-to-cell)
- ✓ **Light set-up** ~ 10 AQMs
- ✓ **Robustness**
- ✓ **Accuracy** < 5-10%



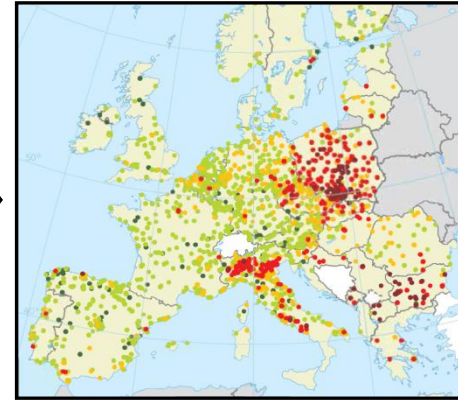
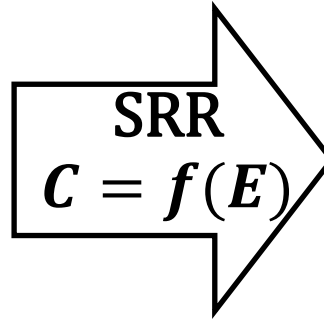
BUT

- ✗ Strong dependence on training model
- ✗ Non linearities neglected
- ✗ Directionality ignored
- ✗ Geographical complexities not accounted

INERIS:
CHIMERE (EU 7km x7 km res)
+ ECMWF 2010
+ EMISSIONS 2009

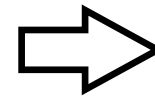
bias in windy areas

bias in mountain areas

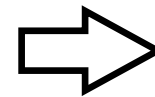


Main assumptions:

- **Delta-SRR** better reproduce AQMs results in respect of absolute-values-SRR
- For long term indicators (**yearly average**) the delta-SRR can be approximated accurately with a **linear function**



$$\Delta C = f(\Delta E)$$



$$\Delta C_j = \sum_p^P \sum_i^N a^{p,ij} \Delta E_j^p$$

p = precursors
 i = source cells
 j = receptor cells



Linear approaches

$$\Delta C_j = \sum_p^P \sum_i^N a^p_{ij} \Delta E_i^p \longrightarrow \text{d.o.f.} = N \times P \quad \text{!!!}$$

p = precursors

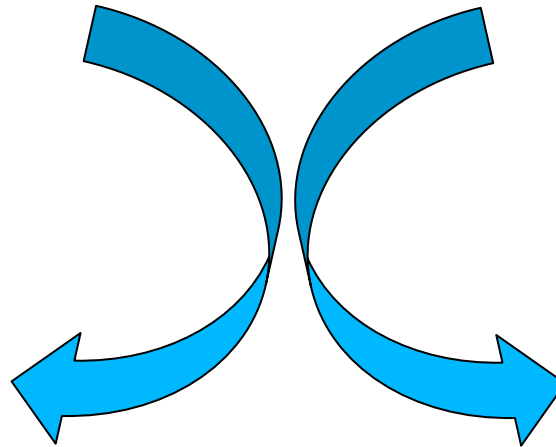
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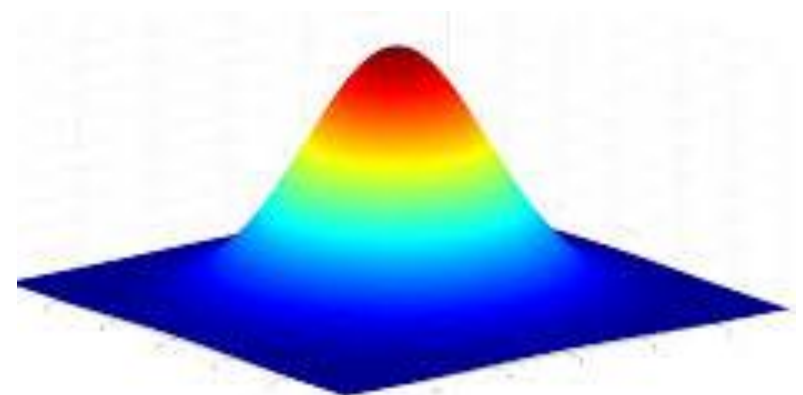
Multi-ring approach

- SOURCE AGGREGATION
- RECEPTOR WINDOWS



Bell-shape approach

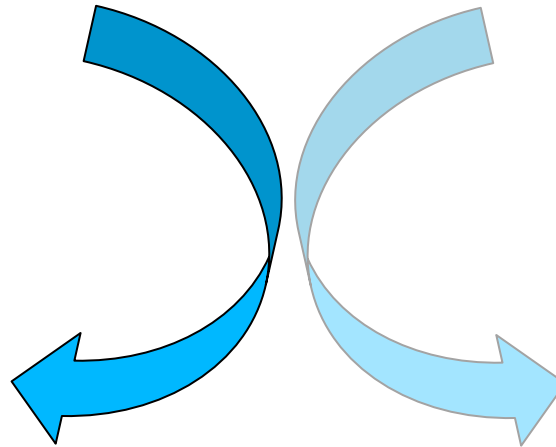
- CELL-TO-CELL RELATIONSHIP DISTANCE WEIGHTED
- ~ RECEPTOR WINDOWS



Linear approaches

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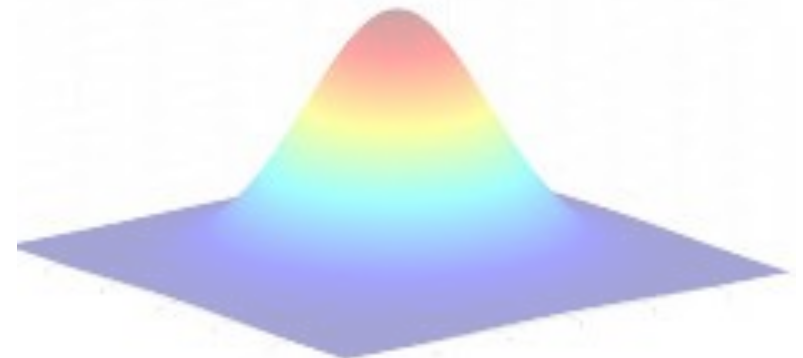
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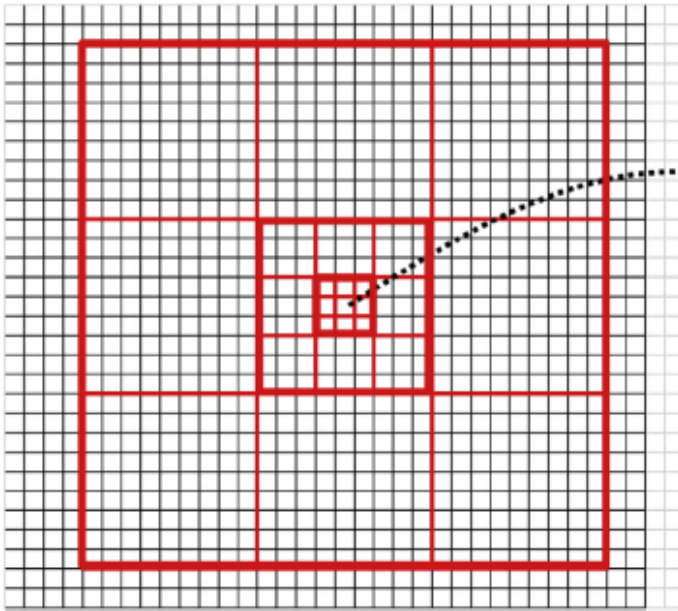




Multi-ring approach



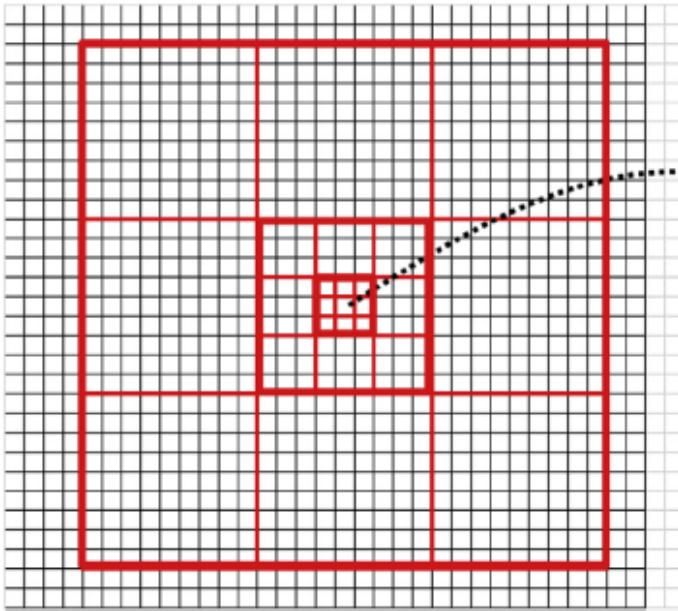
SOURCE AGGREGATION



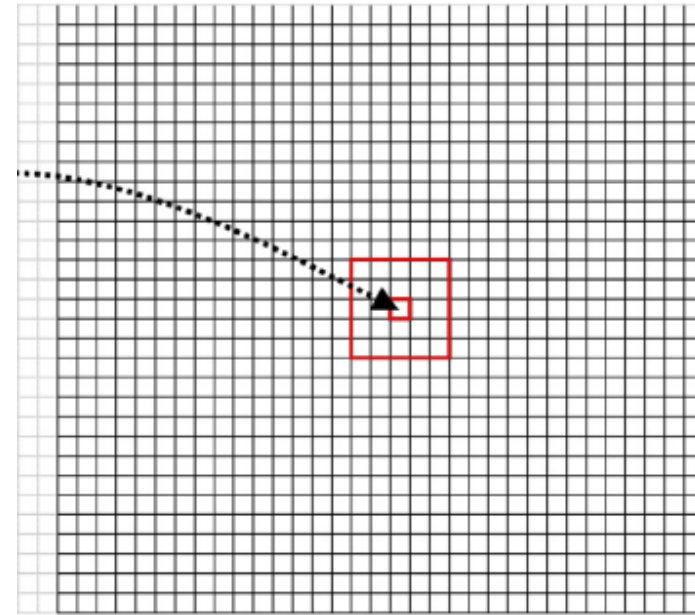
$$\Delta C_j = \sum_p^P \sum_k^{N_A} a^p_{kj} \Delta E_{k,j}^p \longrightarrow \text{d.o.f.} = N_A \times P$$

- p = precursors
- k = source aggregations
- j = receptor cells

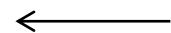
SOURCE AGGREGATION



RECEPTOR WINDOWS



$$\text{d.o.f.} = (N_A \times P) - (N_W \times N_{SC})$$

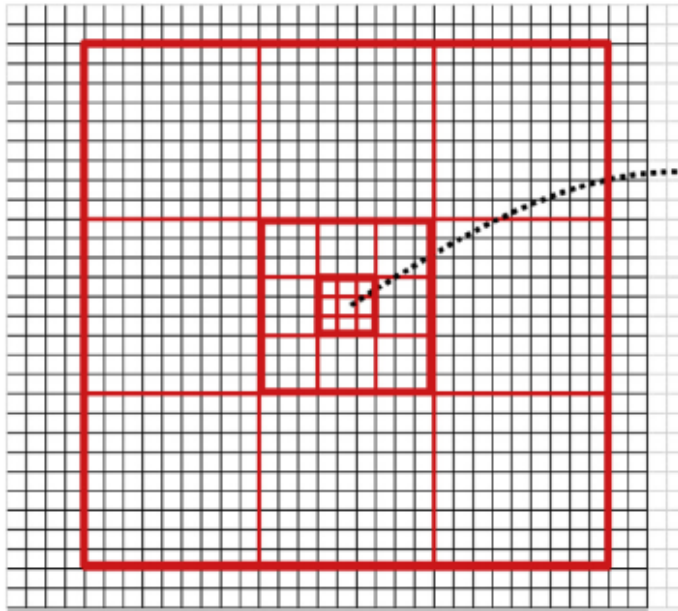


$$\Delta C_j^{SC(1)} = \sum_p^P \sum_k^{N_A} \alpha_{kj}^p \Delta E_{k,j}^{SC(1)p}$$

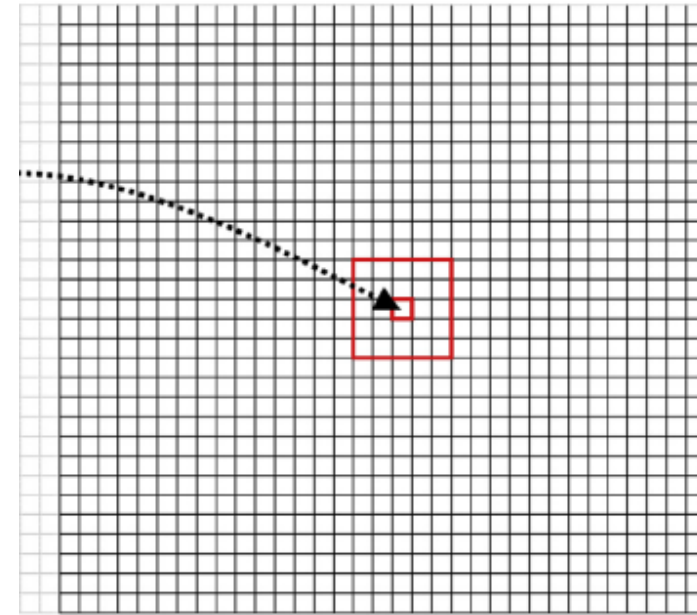
$$\Delta C_{j+1}^{SC(1)} = \sum_p^P \sum_k^{N_A} \alpha_{kj}^p \Delta E_{k,j+1}^{SC(1)p}$$

- p = precursors
- k = source aggregations
- j = receptor cells
- SC = scenario

SOURCE AGGREGATION



RECEPTOR WINDOWS



$$\text{d.o.f.} = (N_A \times P) - (N_W \times N_{SC})$$

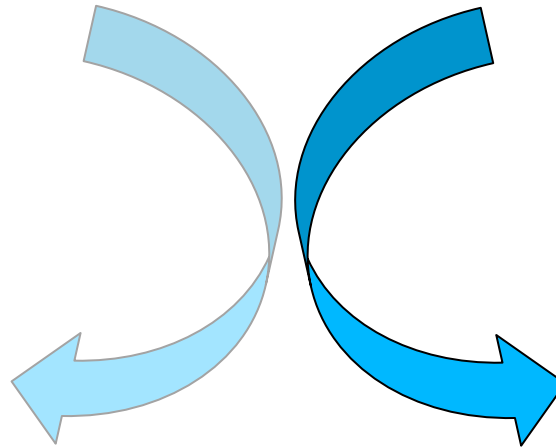
BUT

- ✘ Lack of robustness (small windows)
- ✘ Low accuracy (large windows)

Linear approaches

$$\Delta C_j = \sum_p^P \sum_i^N a^{p}_{ij} \Delta E_i^p \longrightarrow \text{d.o.f.} = N \times P \quad \text{!!!}$$

p = precursors
 i = source cells
 j = receptor cells



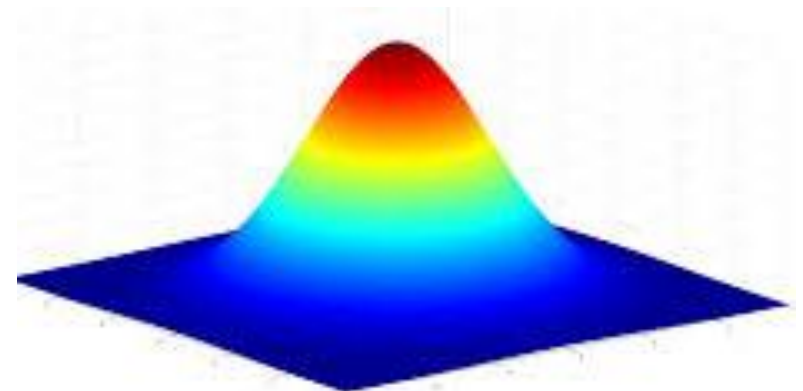
Multi-ring approach

- SOURCE AGGREGATION
- RECEPTOR WINDOWS



Bell-shape approach

- CELL-TO-CELL RELATIONSHIP DISTANCE WEIGHTED
- ~ RECEPTOR WINDOWS

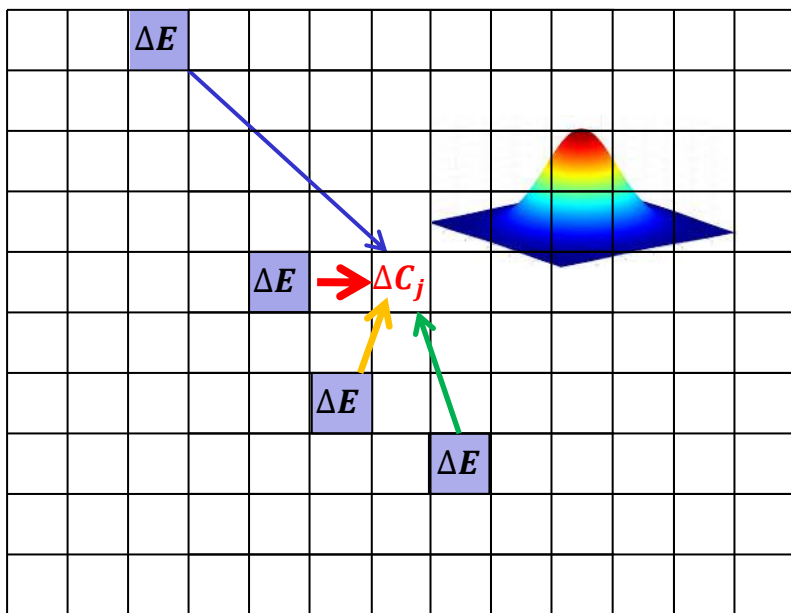




Bell-shape approach



CELL-TO-CELL RELATIONSHIP DISTANCE WEIGHTED



$$a^p_{ij} = \alpha^p_j (1 + d_{ij})^{-\omega^p_j}$$



$$\Delta C_j = \sum_p^P \alpha^p_j \sum_i^N (1 + d_{ij})^{-\omega^p_j} \Delta E_i^p$$

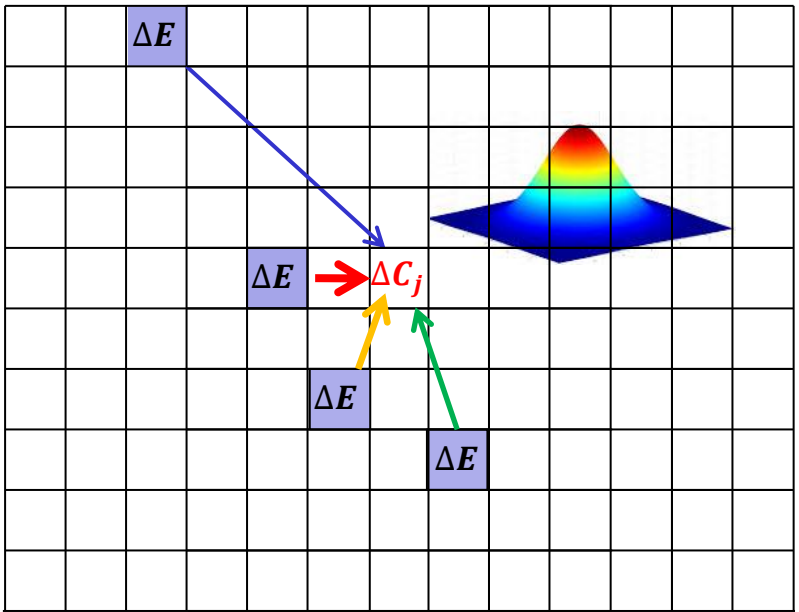
→ d.o.f. = 2 x P



Bell-shape approach



CELL-TO-CELL RELATIONSHIP DISTANCE WEIGHTED



$$a^p_{ij} = \alpha^p_j (1 + d_{ij})^{-\omega^p_j}$$



$$\Delta C_j = \sum_p \alpha^p_j \sum_i (1 + d_{ij})^{-\omega^p_j} \Delta E_i^p$$

→ d.o.f. = 2 x P

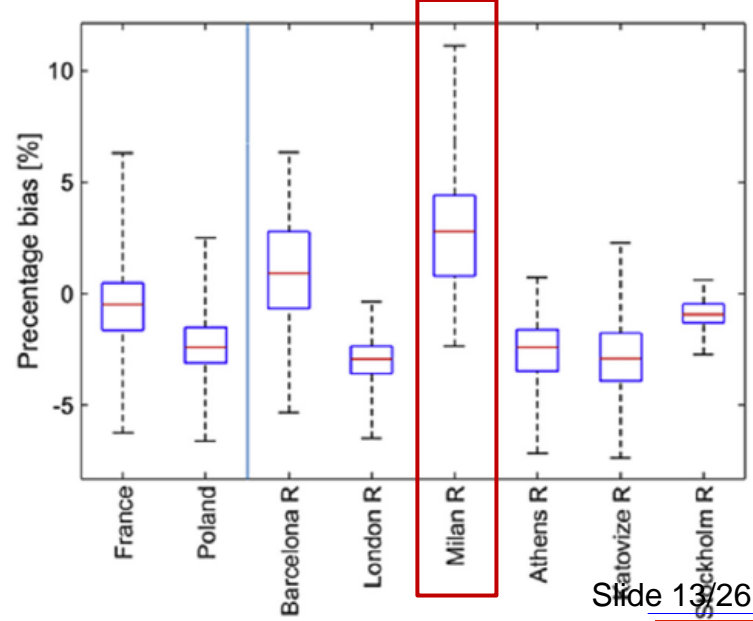
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✗ Directionality ignored

bias in windy areas

✗ Geographical complexities not accounted

bias in mountain areas

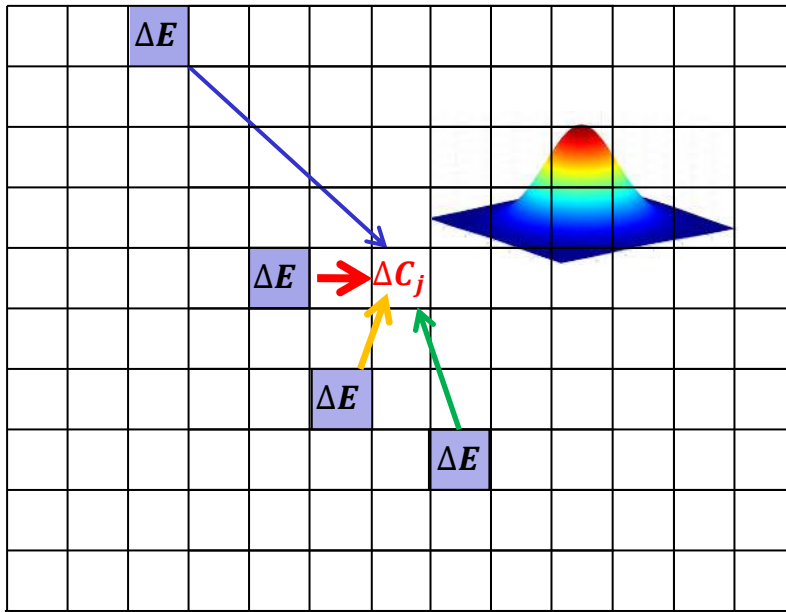




Bell-shape approach



CELL-TO-CELL RELATIONSHIP DISTANCE WEIGHTED



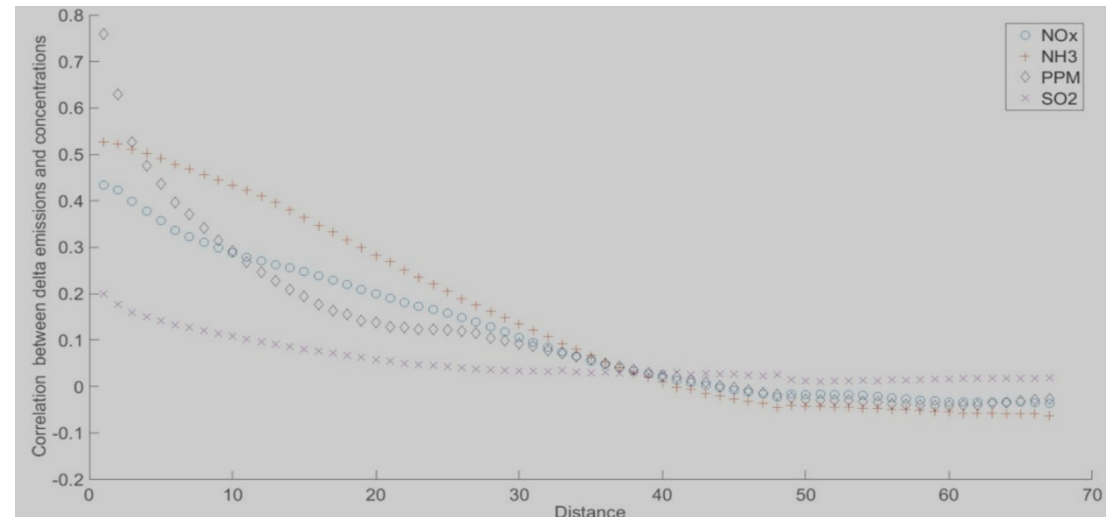
$$a^p_{ij} = \alpha^p_j (1 + d_{ij})^{-\omega^p_j}$$



$$\Delta C_j = \sum_p \alpha^p_j \sum_i (1 + d_{ij})^{-\omega^p_j} \Delta E_i^p$$

→ d.o.f. = 2 x P

- ω ↓ Low spatial variability
 ↑ High precursor dependence
- α ↑ High spatial variability
 ↑ High precursor dependence





SHERPA

SHERPA model

SHERPA Algorithm



$$\Delta C_j = \sum_p^P \alpha^{p_j} \sum_i^N (1 + d_{ij})^{-\omega^{p_j}} \Delta E_i^p$$



STEP 1

Precursors treated independently

Unique R-Window

(or wind speed based, thershold 0.5 m/s)

Least square estimation
between emission and concentration changes

$$\Delta C_j = \sum_p \alpha_j^p \sum_i^N (1 + d_{ij})^{-\omega_j^p} \Delta E_i^p$$



$$\Delta C_j^p = \alpha_j^p \sum_i^N (1 + d_{ij})^{-\omega_j^p} \Delta E_i^p \quad \forall p$$



$$\Delta C_j^p = \alpha^p \sum_i^N (1 + d_{ij})^{-\omega^p} \Delta E_i^p \quad \forall p \quad \forall j$$

—————> d.o.f. = 2



$$\omega^p, \alpha^p \quad \forall j$$



STEP 1

Precursors treated independently

Unique R-Window

(or wind speed based, threshold 0.5 m/s)

Least square estimation
between emission and concentration changes

STEP 2

Emission weighted average delta calculation

All training scenario at the same time
(all precursors reduced contemporarily)

Multi linear regression
between emission weighted average and
concentration deltas

$$\Delta C_j = \sum_p \alpha^p_j \sum_i (1 + d_{ij})^{-\omega^p_j} \Delta E_i^p$$



$$\Delta C_j^p = \alpha^p_j \sum_i (1 + d_{ij})^{-\omega^p_j} \Delta E_i^p \quad \forall p$$



$$\Delta C_j^p = \alpha^p \sum_i (1 + d_{ij})^{-\omega^p} \Delta E_i^p \quad \forall p \quad \forall j$$

—————> d.o.f. = 2



$$\omega^p, \alpha^p \quad \forall j$$



$$\Delta \bar{E}_j^p = \sum_i (1 + d_{ij})^{-\omega^p} \Delta E_i^p \quad \forall p$$



$$\Delta C_j = \sum_p \alpha^p_j \Delta \bar{E}_j^p$$



$$\alpha^p_j$$



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- **Software specifications and hardware requirements**
- **SHERPA Modules**
 - **Source apportionment**
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Software specifications and hardware requirements



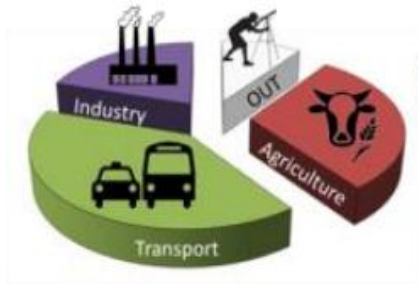
SHERPA (graphical user interfaces - GUIs - and operation processes) is developed on J2SE platform (java 2 standard edition). SHERPA data pre- and post- processing is managed by FORTRAN executables. The core computation module uses PYTHON executable. SHERPA GIS interface is implemented using NASA World Wind. SHERPA is entirely open-source.

SHERPA is developed for Windows operating systems.

The minimum hardware requirements are:

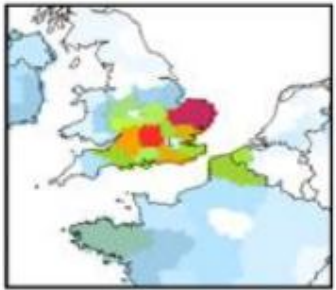
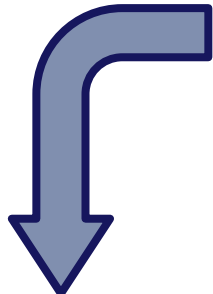
- CPU, no request, the current standard (3 - 3.50GHz) will guarantee an acceptable computation time
 - RAM: minimum 2GB
 - Disk storage: minimum 2GB (each simulation will require additional disk space)
-
- Database (input) and output —→ netCDF, txt

Tasks



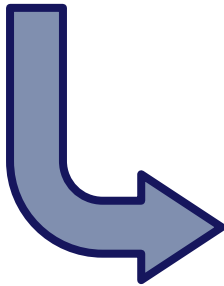
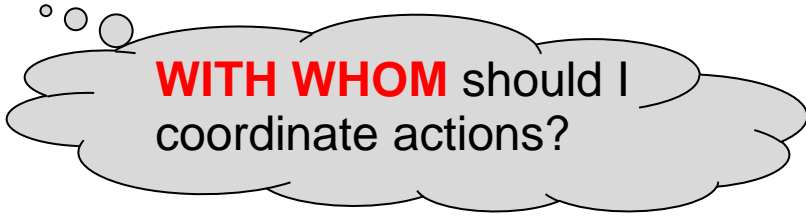
Source allocation

Computes the relative contribution of the various emission sectors/precursors originating inside a region to the amount of pollution in the area



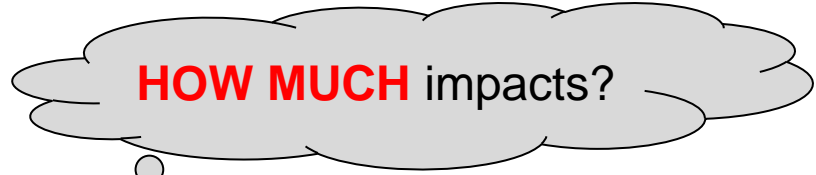
Governance

Identifies the principal source areas of the pollution at a location



Impacts

Tests the impact of an emission reduction scenario in a region



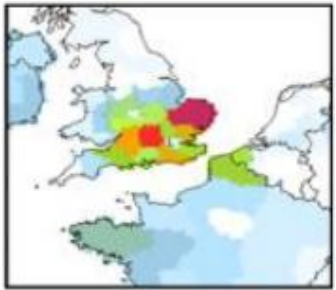
Modules



Source allocation

Module: **SOURCE APPORTIONMENT**

WHAT can I influence?
WHICH sectors/pollutants?



Module: **GOVERNANCE CONTROL AREA**

WITH WHOM should I coordinate actions?

Governance

HOW MUCH impacts?



Impacts

Module: **SCENARIO ASSESSMENT**



Module SOURCE APPORTIONMENT

INPUT

NUTS:

- NUTS0: country areas (e.g. Italy)
- NUTS1: major socio-economic regions (e.g. Nord-Est)
- NUTS2: basic regions for the application of regional policies (e.g. FVG)
- NUTS3: small regions for specific diagnoses (e.g. Udine)

SNAP Macrosectors:

- MS1: combustion in energy industries
- MS2: residential combustion
- MS3: combustion in manufacturing industry
- MS4: production processes
- MS5: fuels extraction and distribution
- MS6: solvent use
- MS7: road transport
- MS8: other transports
- MS9: Waste treatment
- MS10: Agriculture

AQ Indexes:

- NO2
- PM10
- PM2.5
- (O3)

Precursors:

- NOx
- NMVOC
- NH3
- PPM
- SOx



Source apportionment

Altitude 8,867 km Off Globe

Reduction table

	MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10	ALL
NOx	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
NMVOC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
NH3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PPM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SOx	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ALL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
AR											
PT											

x Default reduction levels (50%)

Air Quality Index: PM10

Seasonality: Annual



Module SOURCE APPORTIONMENT

OUTPUT

Absolute or relative potential
(in respect of the base case)

Cells contribution

WHAT can I influence?

Indicator

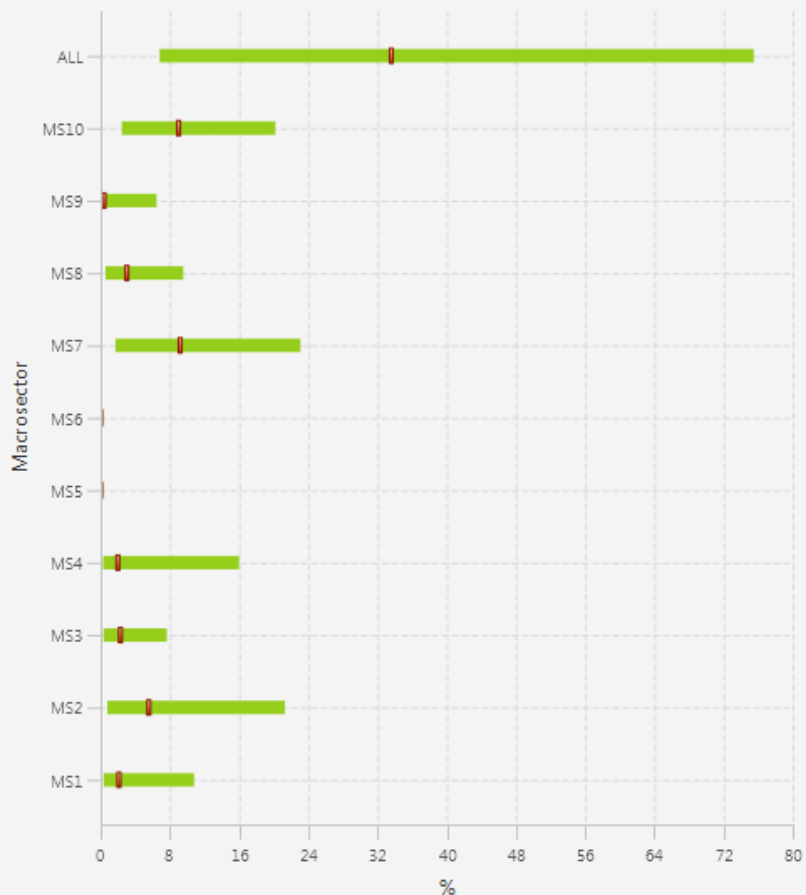
Relative potential

Concentration Percentile

Cell Lat Long

Redraw

Relative potential overview diagram



Source-apportionment diagram



WHICH sectors?



Module GOVERNANCE CONTROL AREA

INPUT

Selected point

Government control area

Back Help

Load config Save config

NUTS level
NUTS 0

Lat
46.115

Lon
12.972

Show point

Altitude 24,000 km Off Globe Downloading

Reduction table											
	ALL	MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10
ALL	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
NOx	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
NMVOG	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
NH3	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
PPM	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
SOx	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
AR	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
PT	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Air Quality Index
PM10

Seasonality
Annual

Map

✘ Default reduction levels (50%)



Module GOVERNANCE CONTROL AREA

OUTPUT

✘ Significance threshold ~1%

WITH WHOM should I coordinate actions?

Order

Friuli-Venezia Giulia
Veneto

Set max 4 OK

Layer options

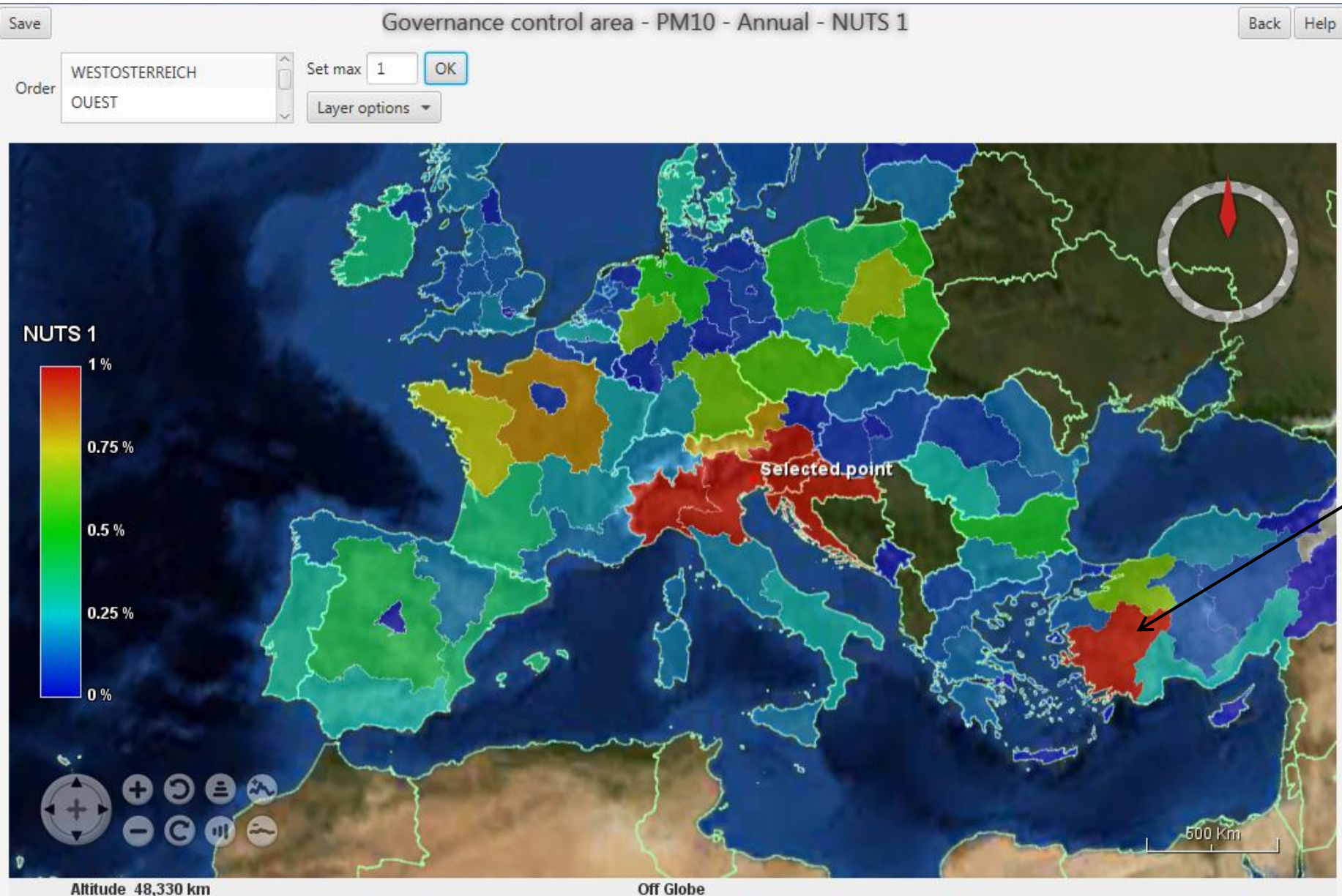
Scale Normalization





Module GOVERNANCE CONTROL AREA

OUTPUT (under significance threshold (1%))



???!!!





Module GOVERNANCE CONTROL AREA

OUTPUT (under significance threshold (1%))

Emissions database (INPUT)

Ncview 1.93@access.nfs

Ncview 1.93g David W. Pierce 24 February 2009

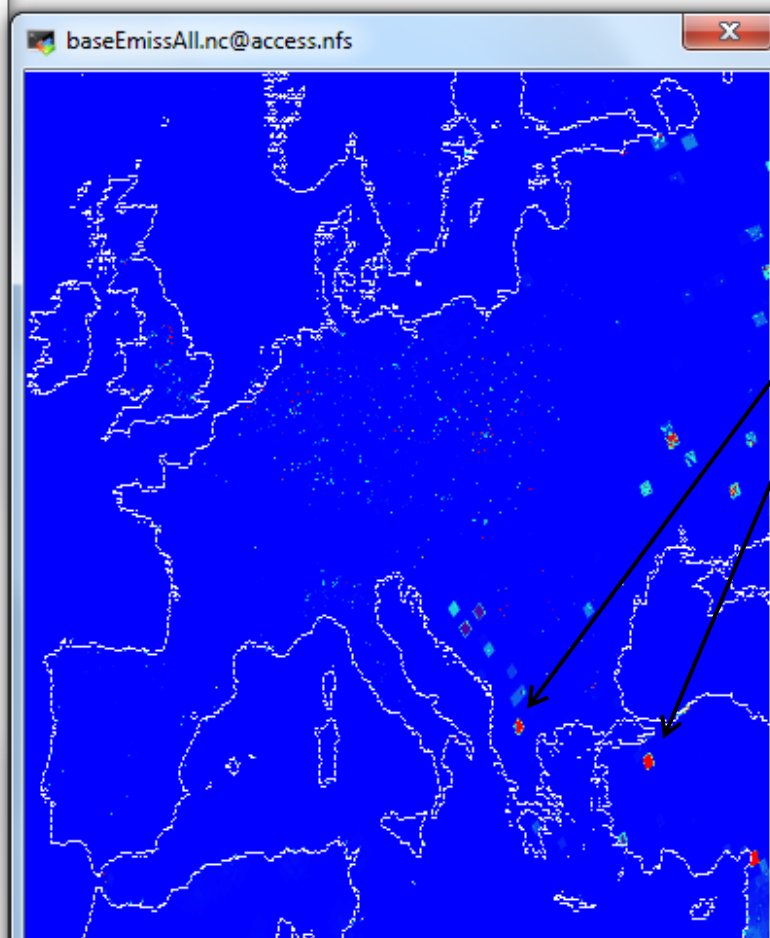
variable=PPM
frame 1/11
displayed range: 0 to 109.644 Mg/km2 (0 to 10 shown)
Current: (i=32, j=433) 0 (x=-6.4375, y=61.09375)

Quit ->1 << < || > >> Edit ? Delay: Opts

3gauss Inv P Inv C Mag X1 Linear Axes Range Bi-lin Print

Var:

Dim:	Name:	Min:	Current:	Max:	Units:
Scan:	Nsnaps	0	<input type="text" value="0"/>	10	-
Y:	latitude	34.0312	<input type="text" value="-Y-"/>	61.9688	degrees_nort
X:	longitude	-10.4375	<input type="text" value="-X-"/>	37.4375	degrees_east





Module SCENARIO ASSESSMENT

INPUT

Scenario Assessment (NUTS) Back Help

- CYPRUS
- CZECH REPUBLIC
- GERMANY
- DENMARK
- ESTONIA
- GREECE
- SPAIN
- FINLAND
- FRANCE
- CROATIA
- HUNGARY
- IRELAND
- ICELAND
- ITALY
 - NORD-OVEST
 - SUD
 - ISOLE
 - NORD-EST
 - Provincia Autonoma...
 - Provincia Autonoma...
 - Veneto
 - Friuli-Venezia Giulia
 - Emilia-Romagna
 - CENTRO (IT)
 - LIECHTENSTEIN
 - LITHUANIA

Altitude 9,288 km Off Globe Downloading

Reduction table											
	ALL	MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10
ALL	0	50	0	30	0	0	0	0	0	0	0
NOx	0	50	0	30	0	0	0	0	0	0	0
NMVOC	0	50	0	30	0	0	0	0	0	0	0
NH3	0	50	0	30	0	0	0	0	0	0	0
PPM	0	50	0	30	0	0	0	0	0	0	0
SOx	0	50	0	30	0	0	0	0	0	0	0
AR	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
PT	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Air Quality Index: NO2

Seasonality: Annual

← Emission reduction scenario (air quality plan)

✓ User defined emission reductions percentages



Module SCENARIO ASSESSMENT

OUTPUT

Concentrations or emissions (precursor, macrosector) maps

SPATIAL RESOLUTION:
gridded or aggregated in nuts
(spatial average, population
weighted, average over threshold)

Save Scenario Assessment (NUTS) - NO2 - Annual Back Help

AQI Data: Delta % Precursor: NOx Macrosector: MS1

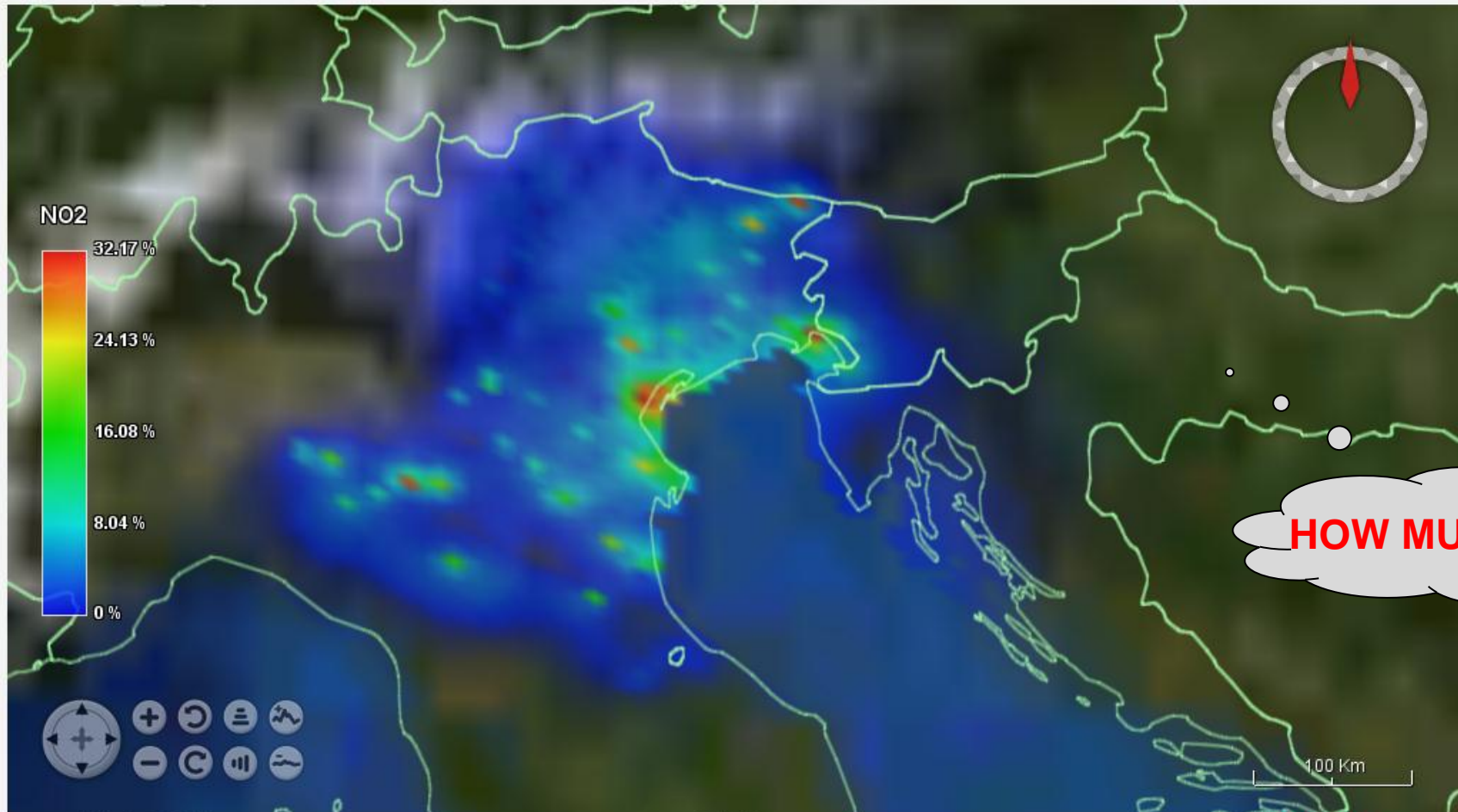
Emission

Gridded Aggregation method: Spatial average Threshold: []

NUTS

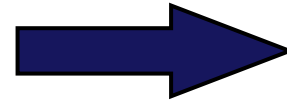
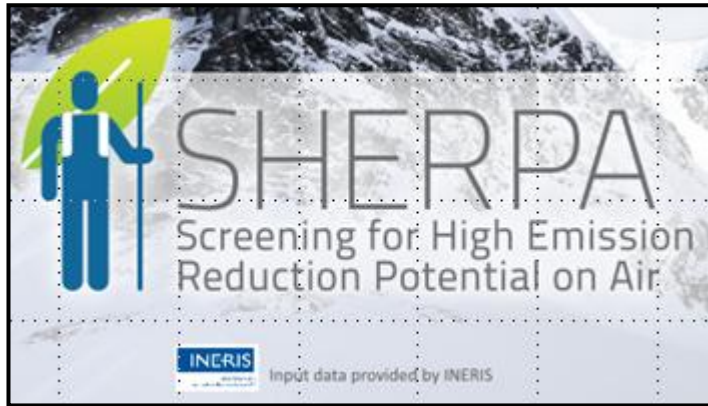
Compute map Set max: Max OK

Layer options



HOW MUCH impacts?

Module FIRST GUESS RIAT+



(cost/effectiveness analysis)

The system will automatically create all the required input files for the RIAT+ tool:

- Domain file;
- Mapping file;
- Emission inventory files;
- GAINS measures database;
- Source-Receptor functions.



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Conclusions

- ✓ SHERPA represents a challenging **user-friendly** tool for the assessment of regional air quality plans

- ✓ Bell-shape methodology provides a good compromise between **accuracy** and **speed**, **spatial flexibility** and **light set-up**

- ✗ But it shows **biases in windy and mountainous areas:**

Is the SHERPA tool suited for analysis in our area?



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References

- **Adding spatial flexibility to source-receptor relationships for air quality modeling**, *E. Pisoni et al.*, Environmental Modelling & Software 90 (2017) 68e77
- **On the design and assessment of regional air quality plans: The SHERPA approach**, *P. Thunis et al.*, Journal of Environmental Management 183 (2016) 952e958
- **SHERPA User Guide**, Version 1.5, *April 2016*
- **SHERPA: a screening tool to support air quality plans**, (slide) *P. Thunis et al.*