Session 1: EI Preparation for Modeling

Emission Inventories and Modeling Activities for the Development of Air Quality Plans in Madrid (Spain)

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OUTLINE

1. Introduction
2. Air Quality Modeling system
3. Emission Inventories
4. Applications and Results
5. Conclusions

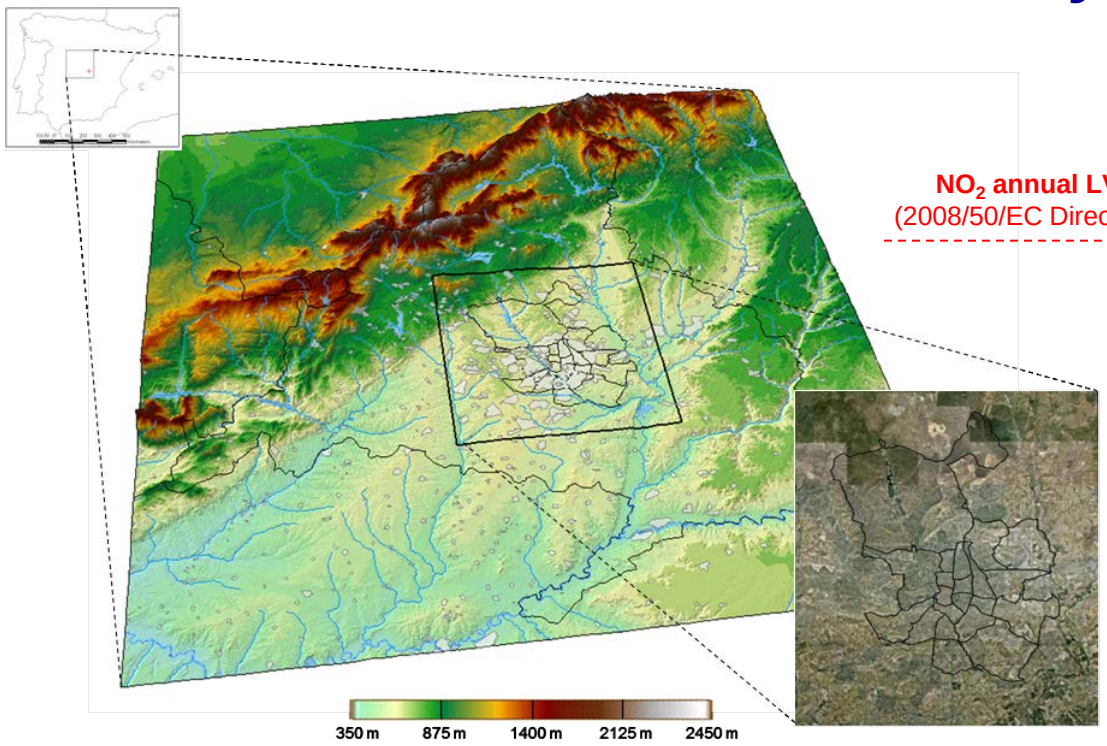
1. INTRODUCTION

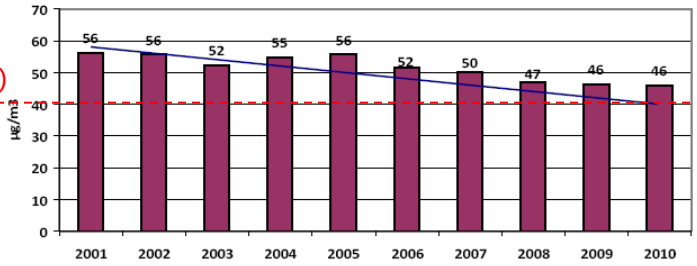
- Modelling is an essential tool for the development of emission abatement measures and air quality plans
- These plans are often related to urban environments
- Air quality modelling in urban areas is very complex:

  - ✓ Multiple pollutants
  - ✓ Multiple sources
  - ✓ Multiple spatial/temporal scales
  - ✓ Model policies and measures (e.g. NO_2)

Requirements for the modeling system and emission inventory

Case study



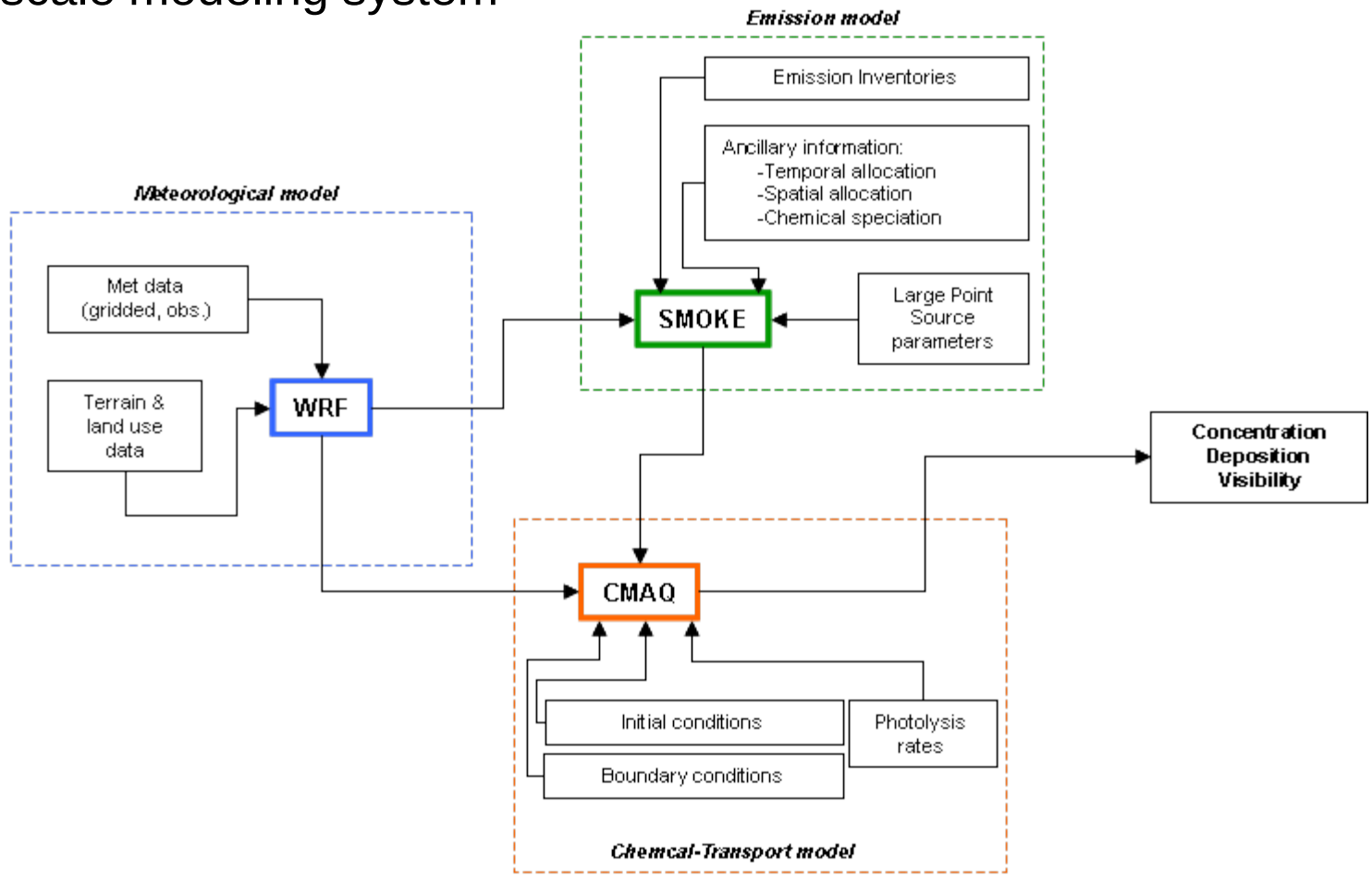


Annual evolution of NO_2 levels (average of a number of representative stations in Madrid)

- Madrid city (Spain): 3.4 million inhabitants in the city, more than 5 million people in the metropolitan area
- Positive trend of AQ in the city. Remaining issues: NO_2

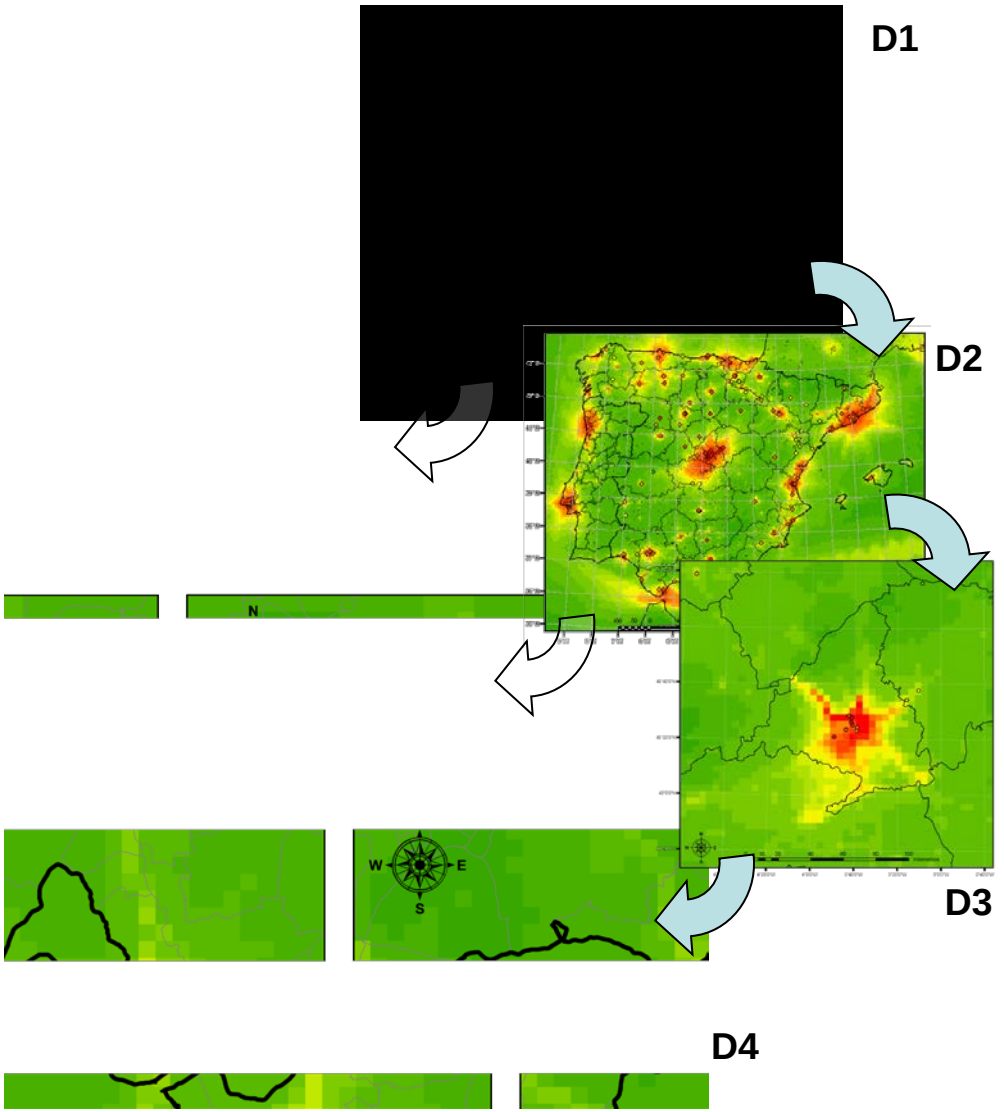
2. AIR QUALITY MODELING SYSTEM

- Mesoscale modeling system



- Four nested domains can consistently describe air pollution processes from continental to urban scale
- Suitable to estimate contributions from different geographic areas (international, national, regional and local)

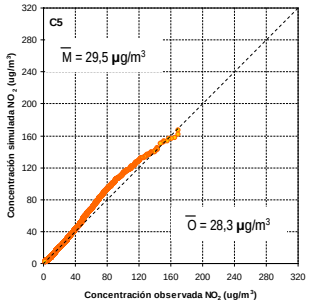
Domain	Spatial resolution (km)	Dimensions (km)		Vertical levels
		x	y	
D1	48	6144	5376	30
D2	16	1200	960	
D3	4	192	192	
D4	1	40	44	

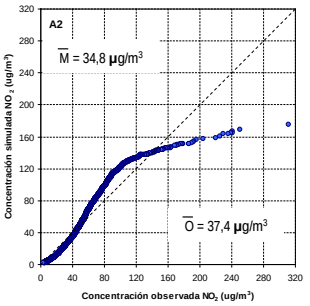


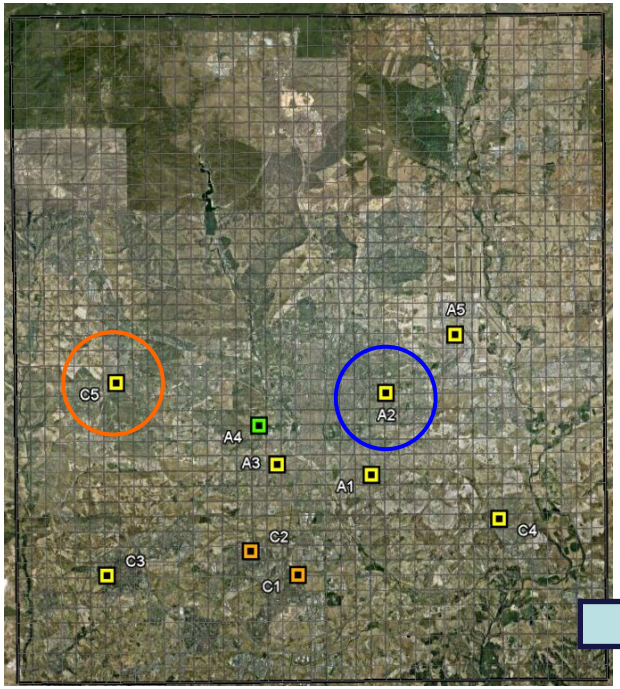
- The system is able to depict urban background levels (e.g. NO_2)

Relative Directive Error (RDE)
Directive 2008/50/EC

$$RDE = \frac{|O_{LV} - M_{LV}|}{LV} \quad *$$



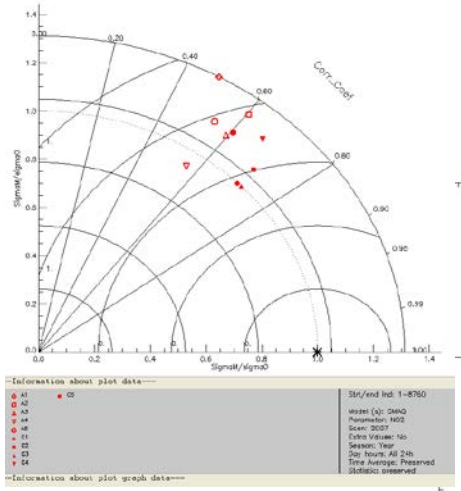


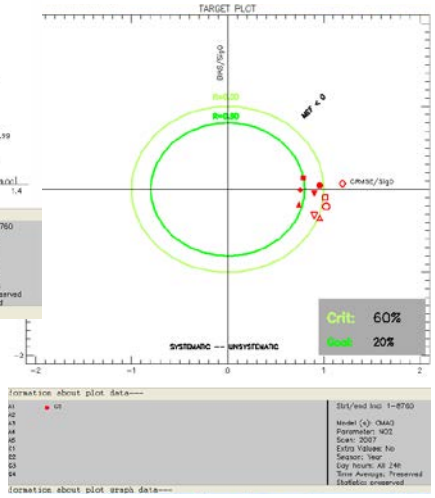


NO_2 uncertainty (MRDE)

Hourly VL = 23,7 %

Annual VL = 22,4 %



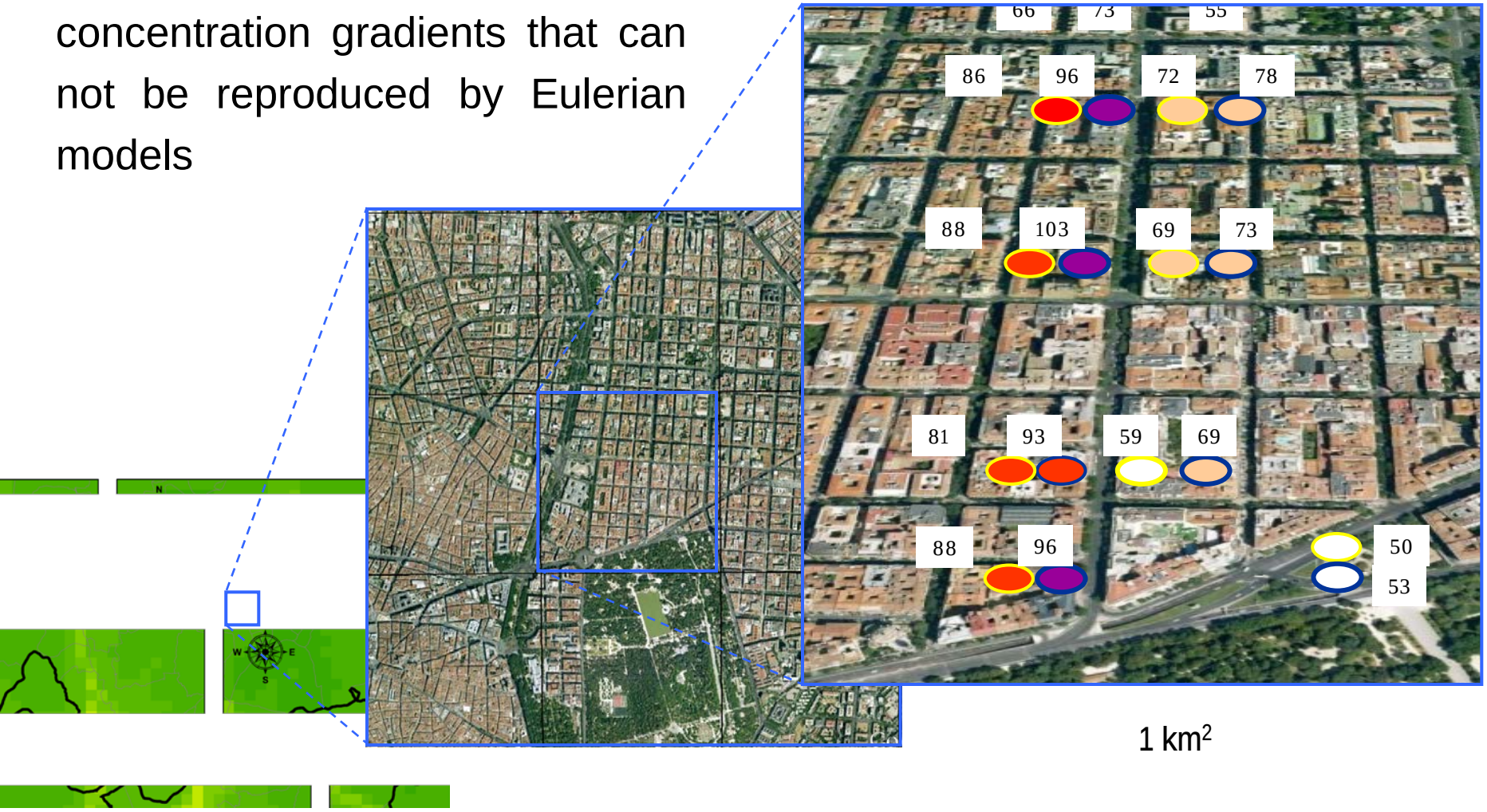


- Acceptable performance (MB = -2.2 µg/m^3; r = 0.63; MFB = -14.1%...)

* where O_{LV} is the closest observed concentration to the limit value concentration (LV) and M_{LV} is the correspondingly ranked modelled concentration. The maximum of this value found at 90% of the available stations is then the Maximum Relative Directive Error (MRDE).

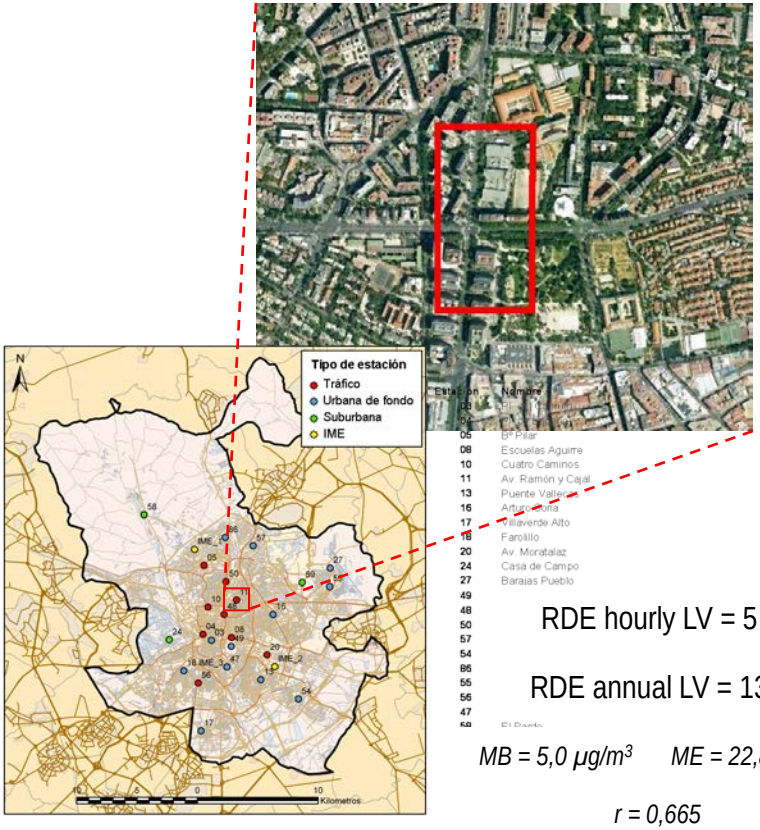
- However, some pollutants such as NO_2 present strong concentration gradients that can not be reproduced by Eulerian models

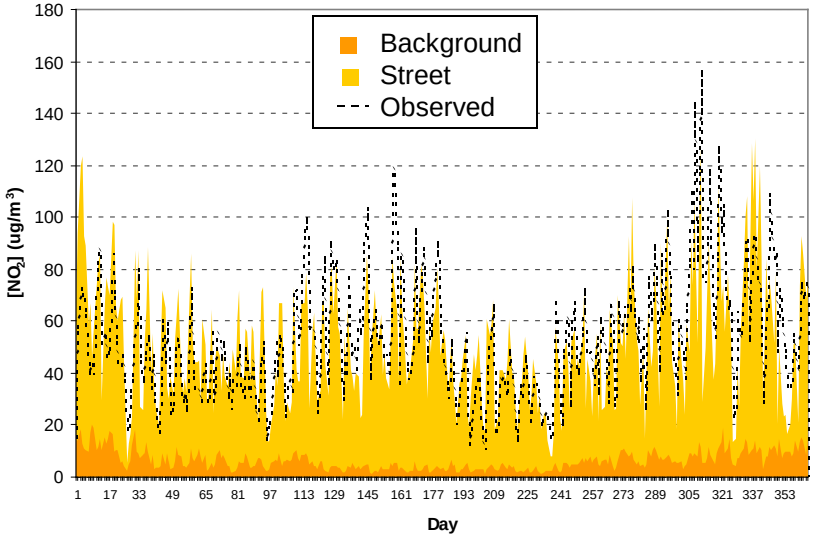
SERCA project. Passive sampling field campaign June-July 2009



Hot spot modeling: OSPM (street canyon model)

Outputs from CMAQ (subtracting street contribution to avoid double counting)



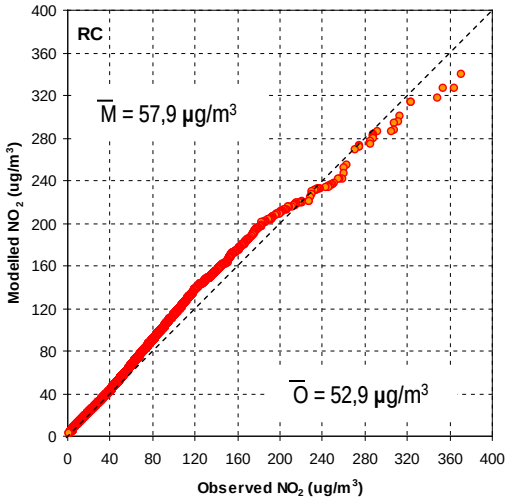


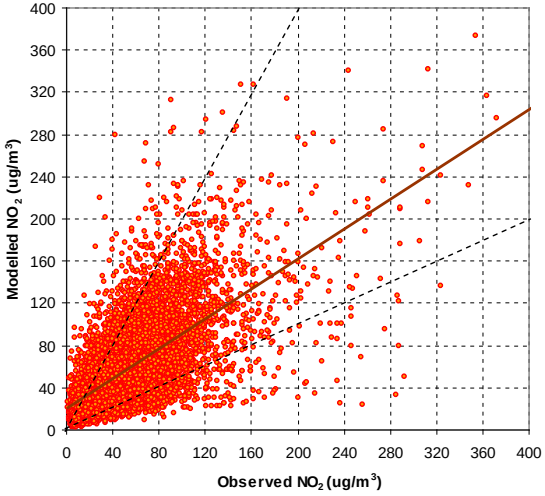
RDE hourly LV = 5 %

RDE annual LV = 13 %

MB = 5,0 µg/m³ *ME = 22,8 µg/m³*

r = 0,665



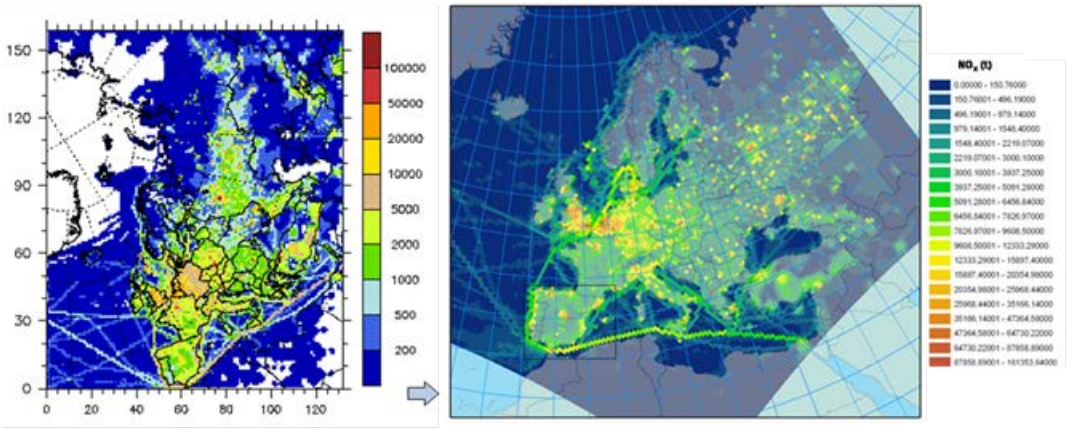


3. EMISSION INVENTORIES

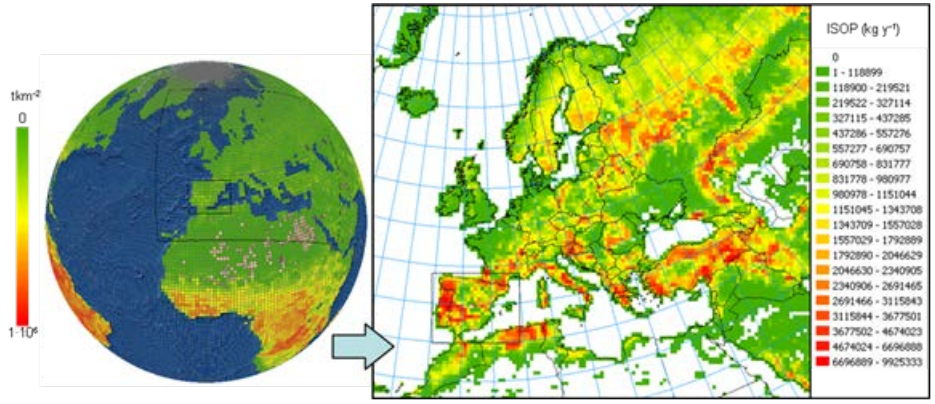
- Key input to air quality models:
  - ✓ One of the main sources of uncertainty (emission estimate and EI preparation for modeling)
  - ✓ Emission abatement as the only way to improve air quality
- Requirements / basic design criteria:
  - ✓ Compatible with AQM requirements
  - ✓ Consistency across the scales / models
  - ✓ Flexible and detailed enough to reflect the outcome of relevant measures ⇒ complete and proportionate
  - ✓ Adaptation to SMOKE framework / concepts

- D1 (Europe)

  - EMEP inventory for anthropogenic emissions (built from national submissions under the Convention on Long-range Transboundary Air Pollution, LRTAP)



  - GEIA for biogenic VOC emissions (Guenther algorithms: computation as well as temporal and spatial allocation)



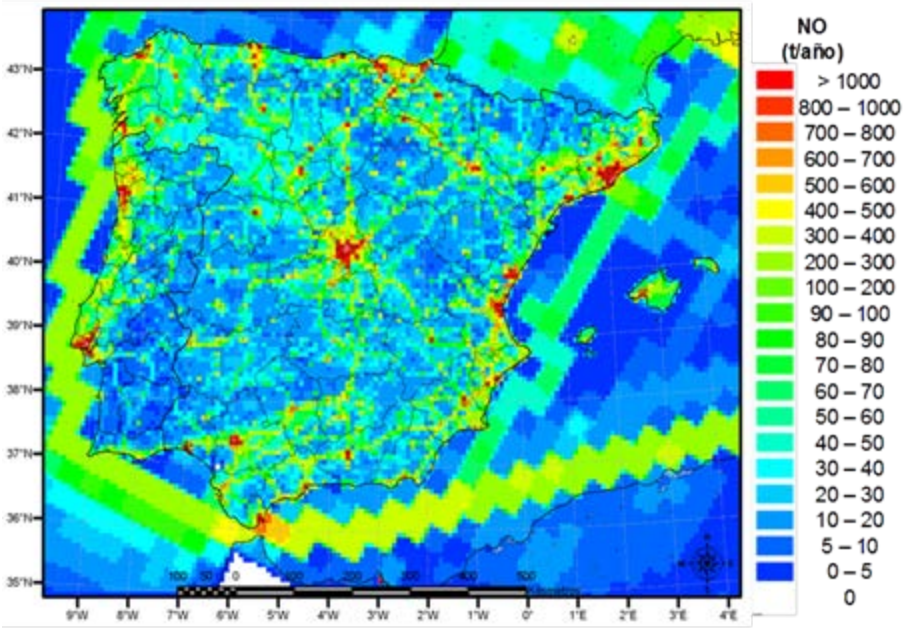
- D2 (Iberian Peninsula)

• Integration of official National Emission Inventories of Spain (SNEI) and Portugal (PNEI):

-184 area-source categories and 62 point-source categories (1720 stacks)

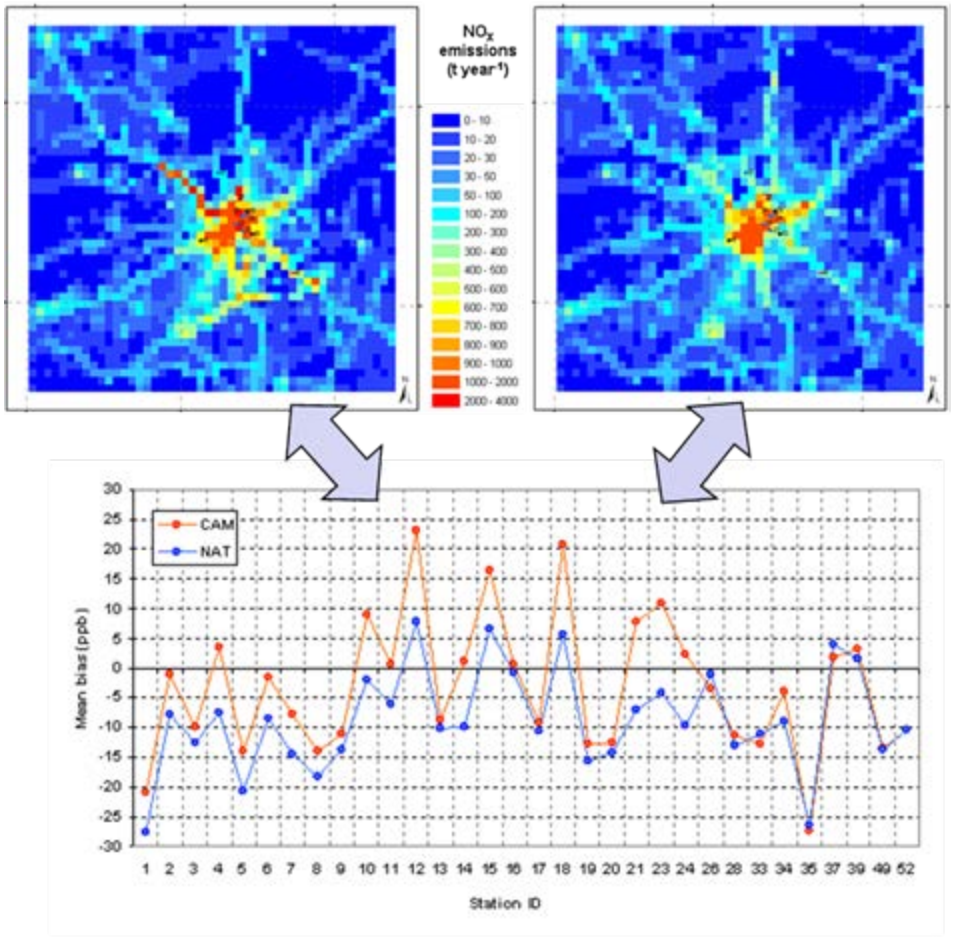
- more than 300 temporal profiles

- more than 200 chemical profiles for VOCs, NO_X and $PM_{2.5}$ (EMEP/EEA guidebook and USEPA ESPECIATE)



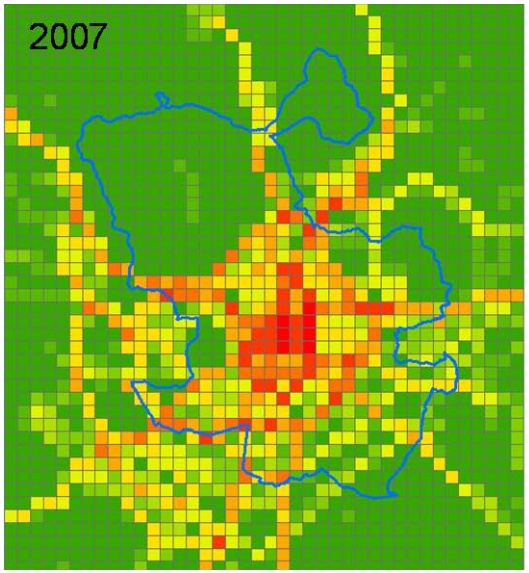
D3 (Greater Madrid Region)

- Combination of two official EI:
  - regional estimates from SNEI
  - Madrid Region Inventory
- Comprehensive analysis, harmonization and assessment through AQ modeling:
  - computation methods
  - activity data
  - ancillary information



D4 (Madrid metropolitan area)

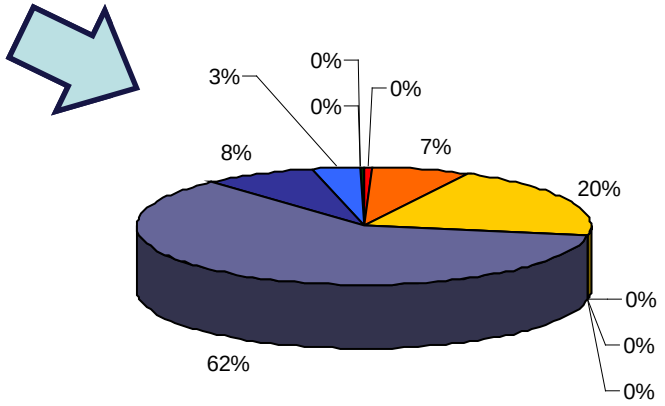
- Ad-hoc inventory that combines official estimates and highly detailed specific bottom-up estimates for the most relevant sectors:



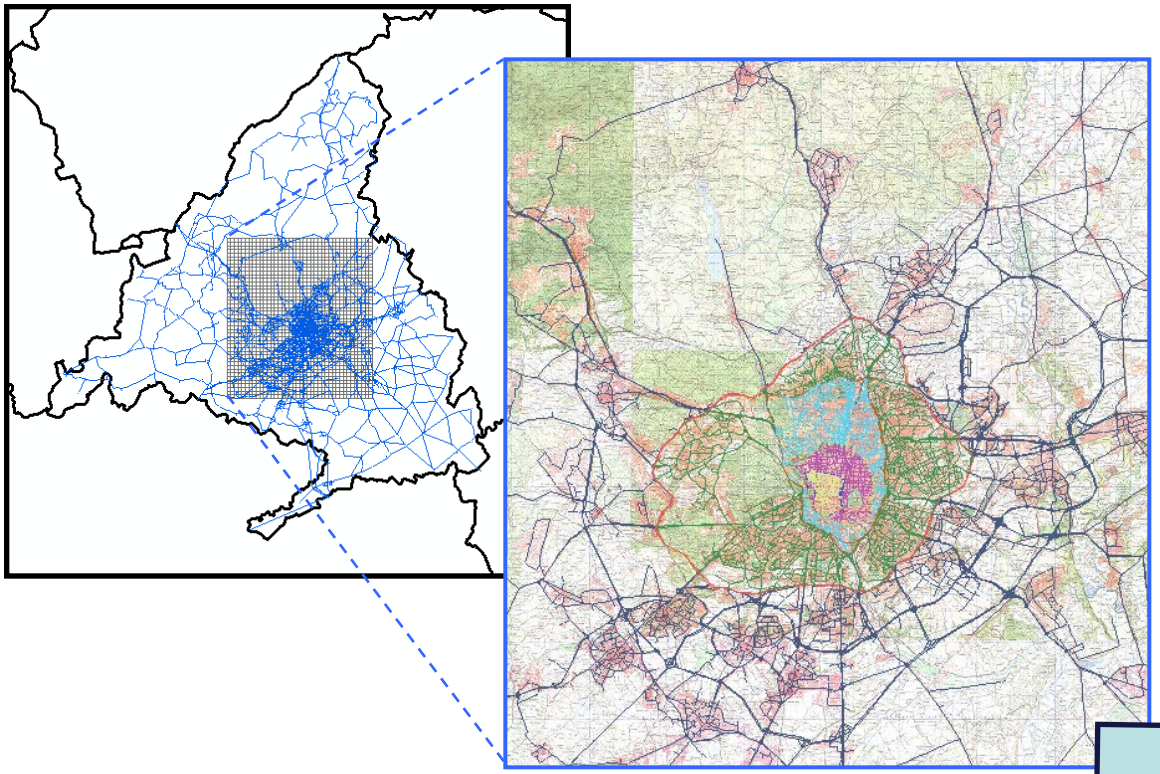
NO_x emissions (t/yr)

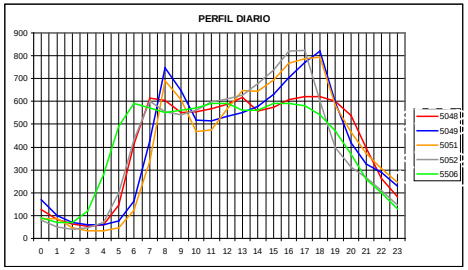
150 – 200
100 – 150
75 – 100
50 – 75
30 – 50
20 – 30
15 – 20
10 – 15
5 – 10
0 – 5

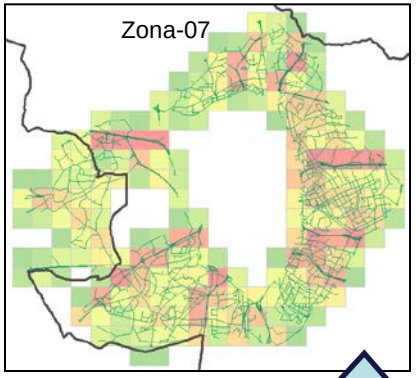
Grupo SNAP	CO	NH3	NOX	PM10	PM25	SO2	VOC	ISOP	TERP	OVOC
1	225	0	243	50	29	1128	1	0	0	0
2	10004	0	3680	520	410	2731	1104	0	0	0
3	2238	0	10689	265	210	2494	1217	0	0	0
4	1083	130	108	51	32	70	3782	0	0	0
5	0	15	0	0	0	0	2056	0	0	0
6	0	212	0	0	0	0	48828	0	0	0
7	59712	496	32102	1736	1452	147	14205	0	0	0
8	2711	0	4171	360	360	287	769	0	0	0
9	441	2036	1769	26	26	6	5267	0	0	0
10	357	1543	56	90	13	0	17	0	0	0
11	32	605	125	0	0	0	233	1013	2574	862
TOTAL D4	**76803**	**5037**	**52942**	**3098**	**2533**	**6863**	**77479**	**1013**	**2574**	**862**

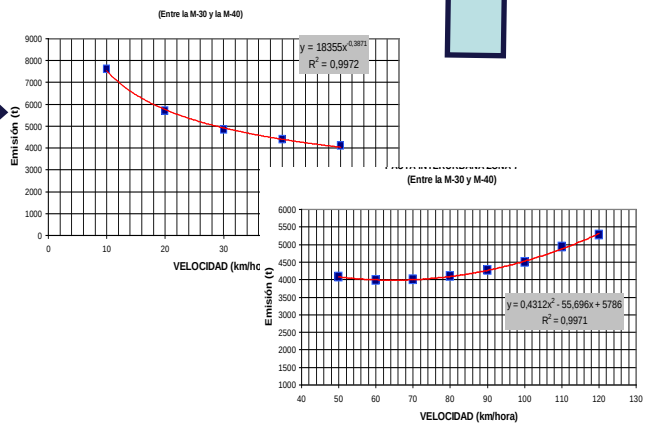


- Key feature: integration with the regional traffic model (TDM) for emission computation at link level (15 000 aprox.)



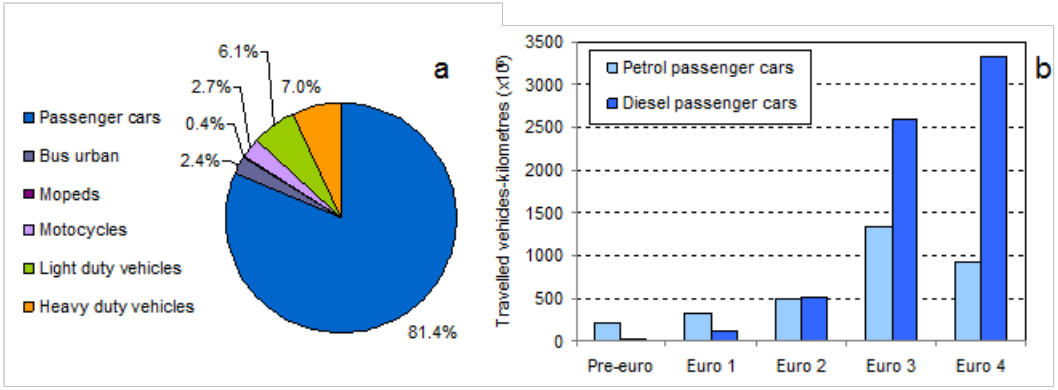






Zonas	Autobuses	Pesados	Taxis	Motos	Ciclomotores	Ligeros	Turismos
Interior 1º cin.	4,84%	7,42%	15,91%	6,08%	1,21%	5,25%	59%
En el 1º cint.	2,22%	6,43%	13,32%	3,59%	0,72%	5,68%	68%
Entre 1º y 2º cint.	2,77%	5,95%	15,25%	4,62%	0,92%	5,59%	65%
En el 2º cint.	2,67%	5,70%	8,33%	2,73%	0,54%	5,76%	74%
Entre 2º cint. Y M-30	1,93%	5,58%	9,18%	3,54%	0,71%	5,76%	73%
En la M-30	1,53%	6,26%	3,88%	1,80%	0,00%	8,86%	77,67%
Entre M-30 y M-40	2,58%	7,56%	5,78%	2,27%	0,45%	5,68%	76%
En la M-40	2,58%	7,56%	5,78%	2,72%	0,00%	5,68%	75,67%
Exterior a la M-40	2,58%	7,56%	5,78%	2,27%	0,45%	5,68%	76%

- Hourly resolved intensity and speed from the traffic model at link level
- Vehicle mix (types) from the traffic model at management area level
- Fleet characterization (age and technology) from field campaigns



- Emissions computation according to COPERT (only urban driving pattern). Modeling in SMOKE:
  - ✓ 63 inventory categories (7 vehicle types x 9 management areas)
  - ✓ 63 NO_X speciation profiles and 9 VOC speciation profiles (COPERT)
  - ✓ 9 (management areas) spatial surrogates (by grid overlapping)

•This design incorporates all the information available and allows the simulation of any of the potential measures for the sector:

-Low emission zones (access restrictions by vehicle type, age or technology)

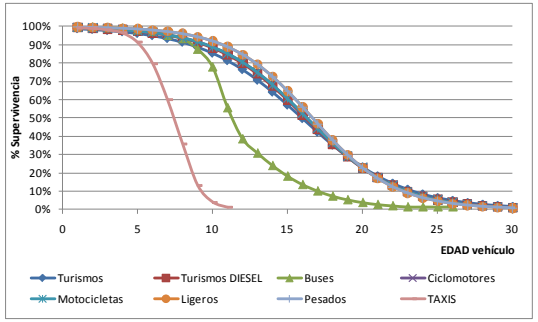
-Speed limits

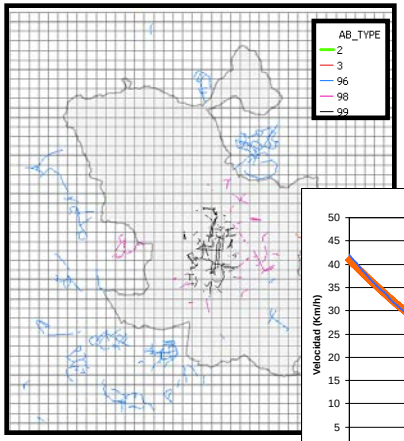
-Penetration of new technologies (combustion engines standards, hybrid and electric vehicles, etc.)

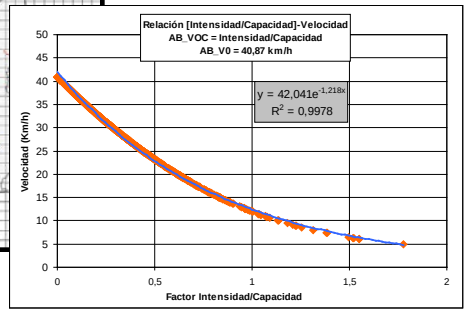
-Specific fleet turnover and limitations by segments (buses, taxis, light duty vehicles, passenger cars, etc.)

-Measures to alleviate urban congestion

Impact on the variables/parameters involved in emission computation





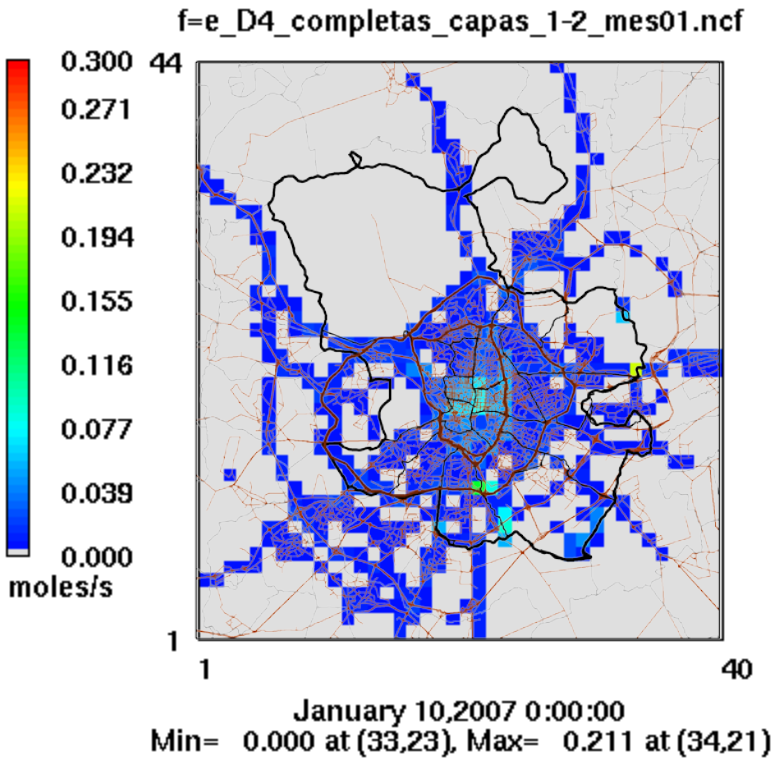


3. APPLICATIONS AND RESULTS

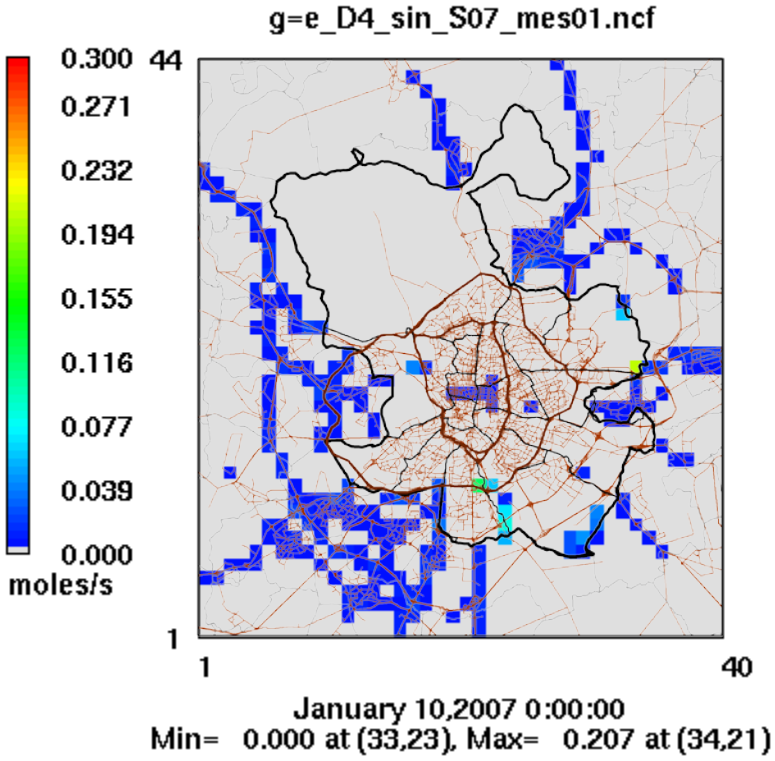
- Source apportionment (sensitivity analysis):
  - ✓ Basic emission abatement strategy / course of action
  - ✓ Maximum feasible AQ improvement related to the main emitting sectors
  - ✓ Quantification of external constrains
  - ✓ Legal requirement to apply for the NO_2 compliance postponement
- Basic methodology: zero-out:
  - ✓ Comparison of on/off model results for a particular sector
  - ✓ Comparison of model results with alternative BC and geographical masks

- E.g. contribution of local road traffic - emissions

NO emissions (all sources)

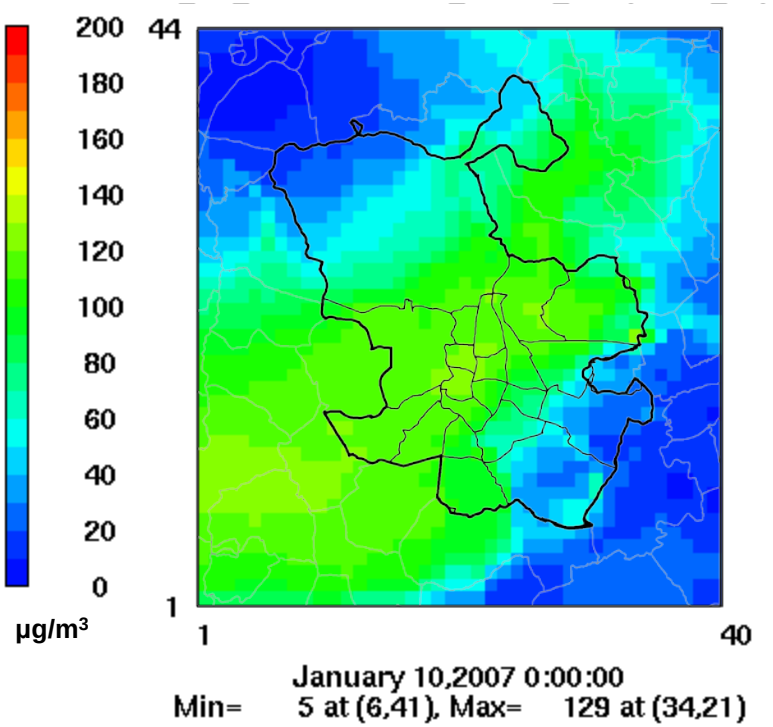


NO emissions (excluding road traffic in Madrid city)

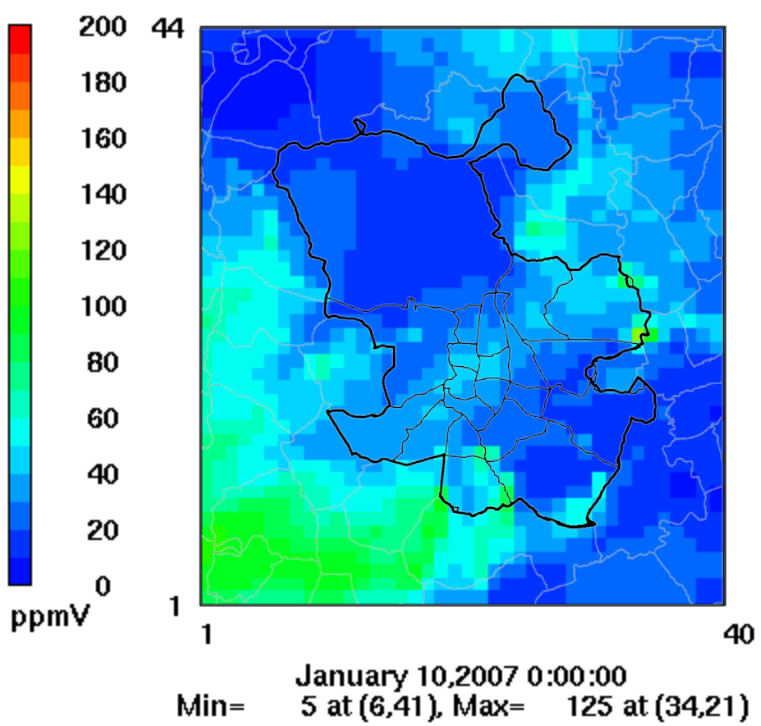


- E.g. contribution of local road traffic – model response (NO_2 concentration)

Base or reference

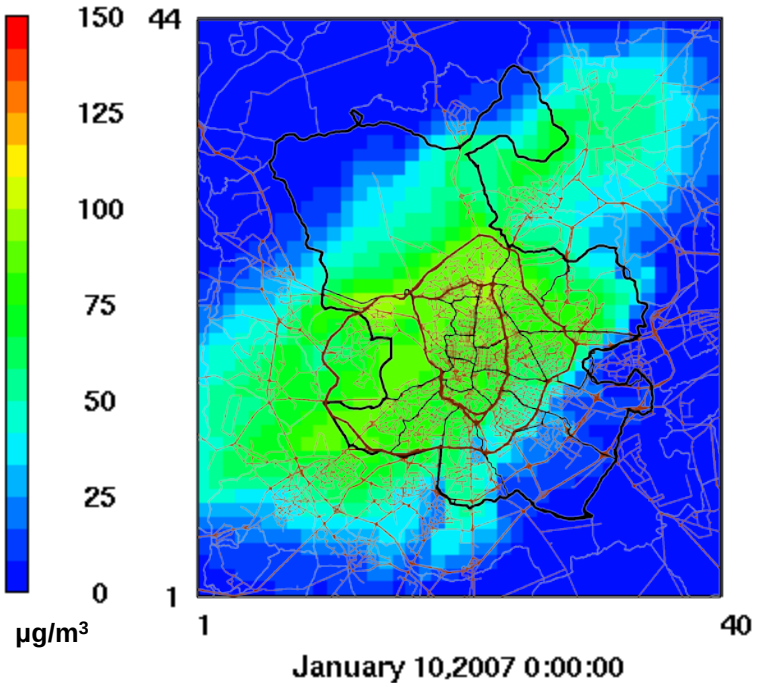


No local road traffic

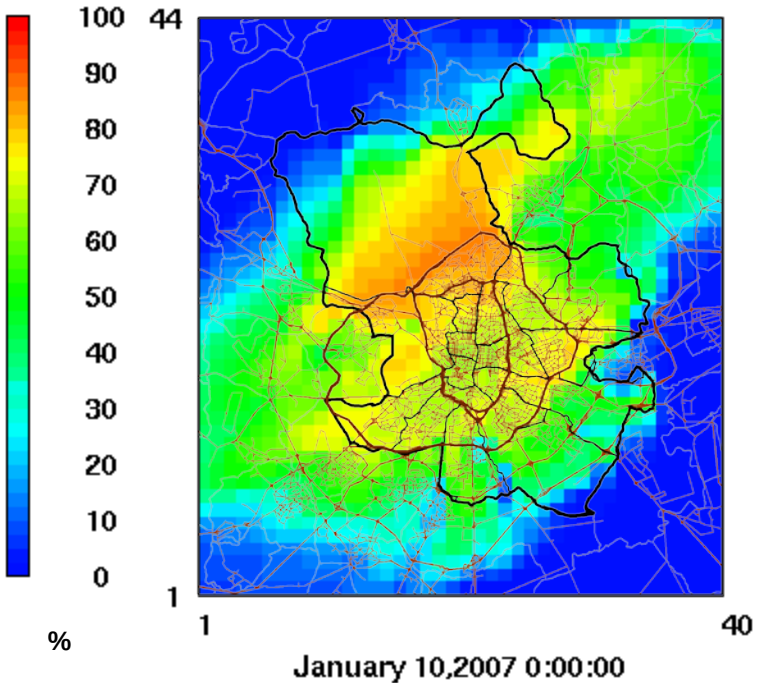


- E.g. contribution of local road traffic – comparison and apportionment

Absolute

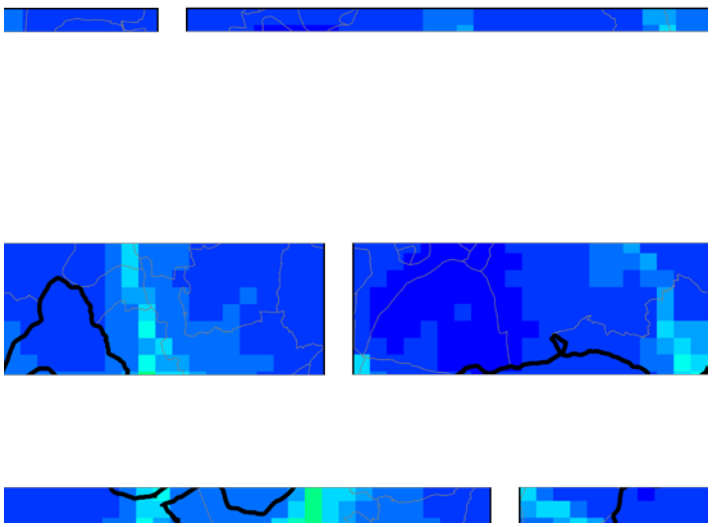


Relative

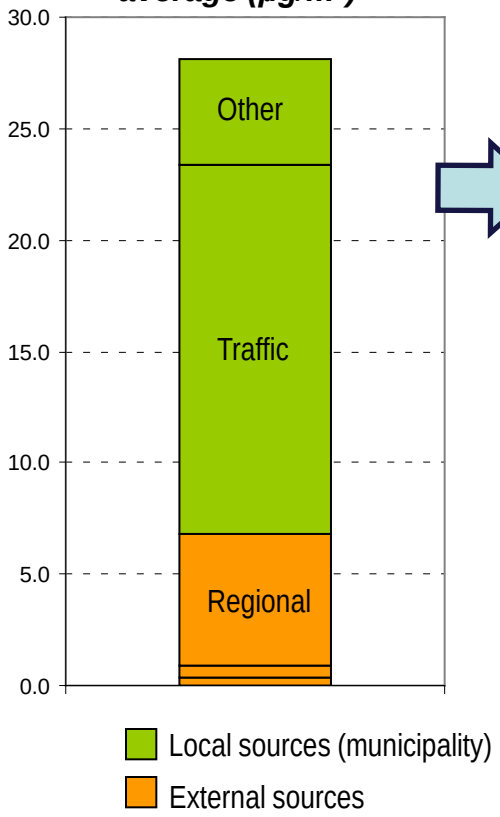


- In general, Madrid is strongly dominated by local sources, mainly road traffic
- National and international influence is negligible

Madrid average concentration = 28,1 µg/m³



Apportionment to NO_2 annual average (µg/m³)



Measures aimed at limiting local road traffic with an additional effect at regional level (metropolitan area)

Scenario development and assessment

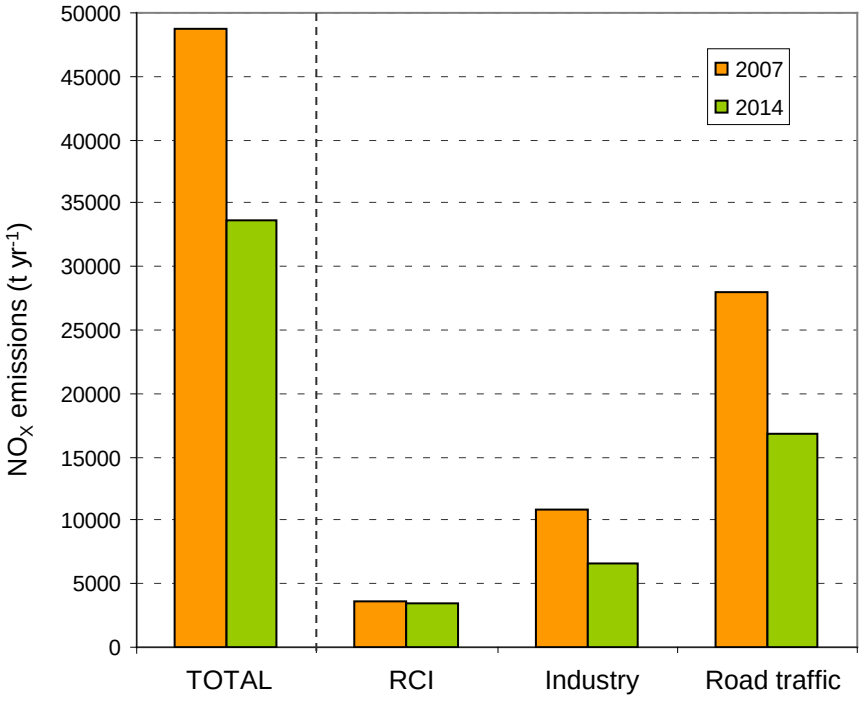
- Main considerations for the development of future-year scenarios:

  - ✓ abatement measures focused on the emission sectors responsible for air pollution (according to the source apportionment study)
  - ✓ emission projection model consistent with emission model/methods used for the reference year
  - ✓ transparency and documentation, highlighting critical hypotheses and parameters

- Madrid Air Quality Plan (for NO_2 compliance by 1st January 2015)

- Up to 70 abatement measures have been assessed and evaluated

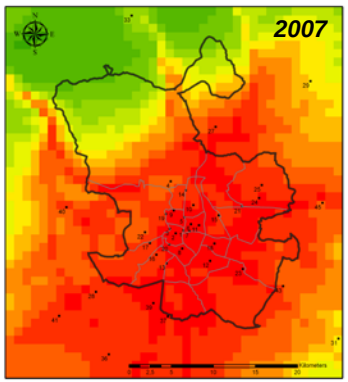
- A global decrease of 31% in NO_X emissions is expected, mainly due to measures in the road transport sector (40% decrease)

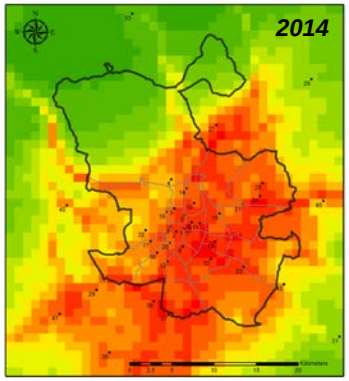


Outputs (air quality):

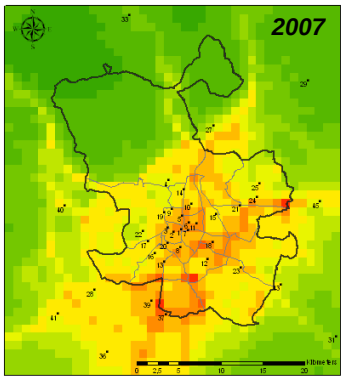
- Compliance expected before 2015
- Results to be complemented by microscale measures / modelling

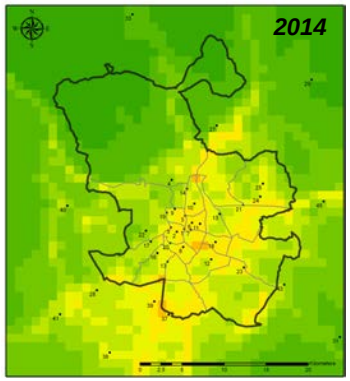
Annual 1h 99.8th percentile (1-h LV)





Annual mean (Annual LV)

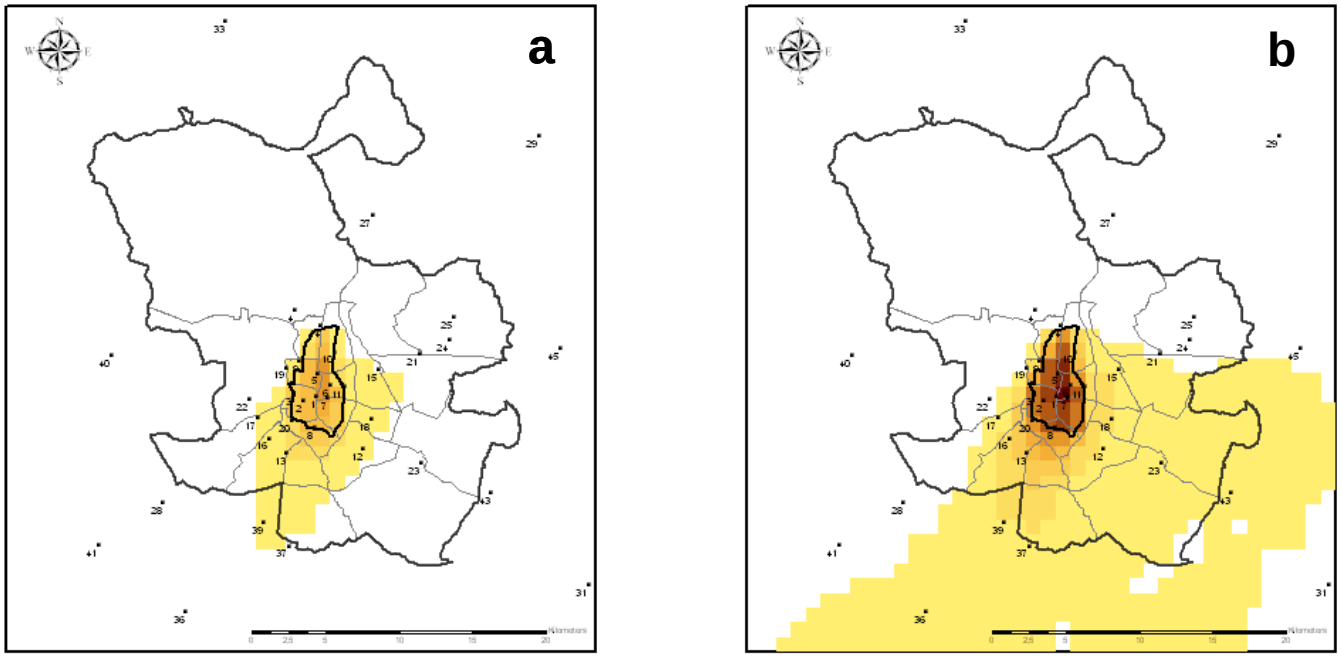




-Annual NO_2 levels reduced by 34% as an average; approximately 15 µg/m^3 in the city center

-Important impact in the metropolitan area (-7 µg/m^3 as an average in the modeling domain)

- The AQ Plan assessment includes some additional measures intended for pollution episodes, such as exceptional restrictions for application in the LEZ



Impact of passenger cars access restriction by 20% (a) and 50% under unfavorable meteorological conditions (24-h average NO_2)

5. CONCLUSIONS

From the case study

- Meeting the Limit Value (LV) for NO_2 in urban environments is a rather challenging issue
- NO_2 ambient concentration values in Madrid are strongly dominated by local sources with a remarkable contribution from road traffic
- According to the results of this study, cutting down NO_X emissions by 31% would allow the fulfillment of NO_2 limit values in Madrid by the end of 2014
- Further modeling activities are needed to assess complementary microscale measures in specific hot spots

General

- The analysis and design of Urban Air Quality Plans (UAQP) is a very complex task that has to be supported by suitable air quality modeling tools

- Emission inventories play a critical role in the development of UAQP. They should meet a series of requirements:
  - Consistency across the scales, air quality models and projection methods
  - Flexible and detailed enough to accurately reflect the effect of any abatement option

- The SMOKE modeling system has been proved a useful tool to support this kind of development for the Madrid Metropolitan Area

Thank you for your attention!

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