8th meeting of the Task Force on Measurement and Modelling

UNECE

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CMAQ activities in Spain

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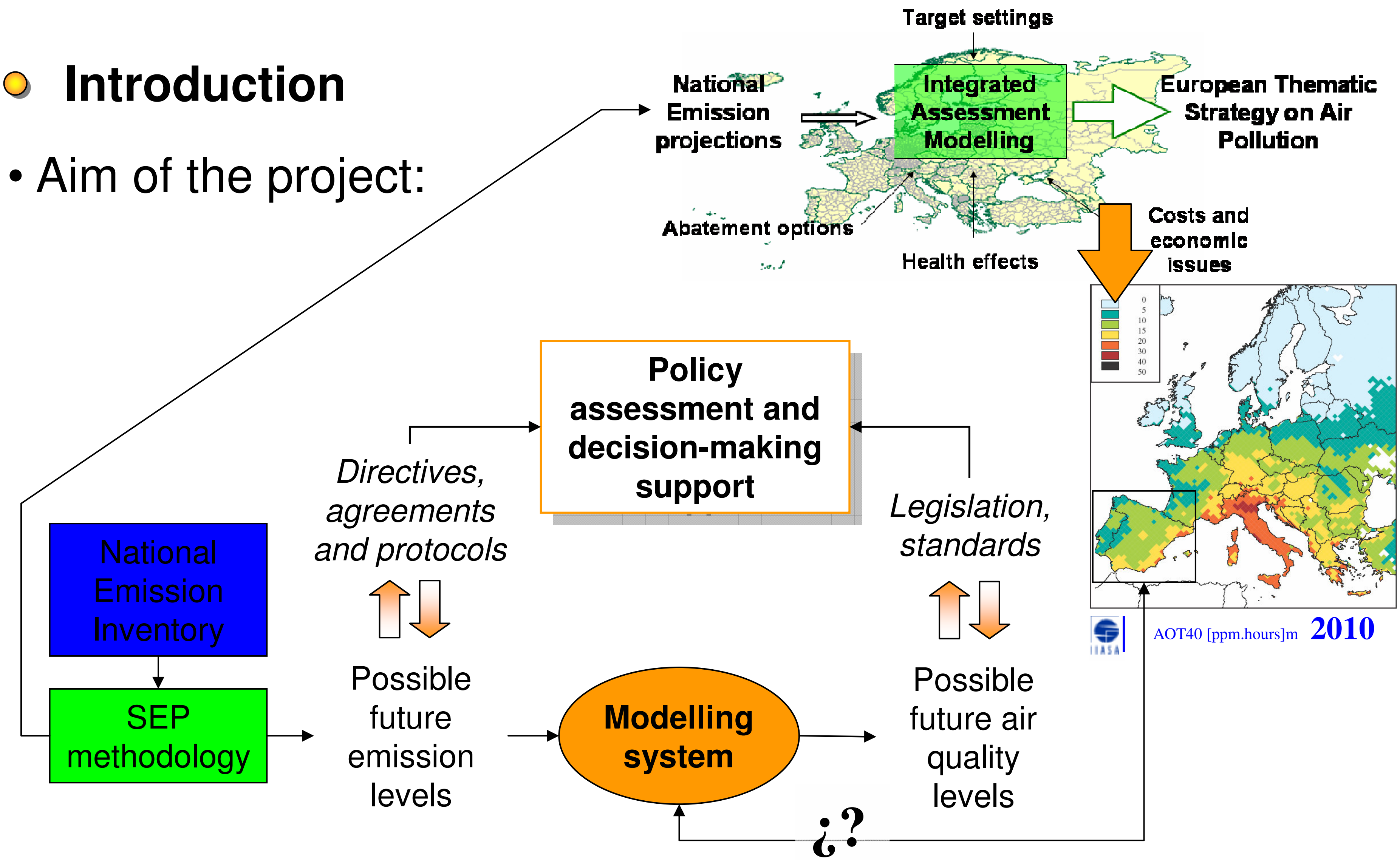
INTRODUCTION

RECENT ACTIVITIES

THE SIMCA PROJECT

Introduction

- Aim of the project:



implementation of an integrated air quality modelling system for Spain

- Assessment and comparison of environmental policies and control strategies
- Based on national projections from the Spain's Emission Projection (SEP) project, funded by the Spanish Ministry of Environment

MINISTERIO DE MEDIO AMBIENTE

- Still a work in progress
- Some results for tropospheric ozone simulations over the Grater Madrid Area (2010)

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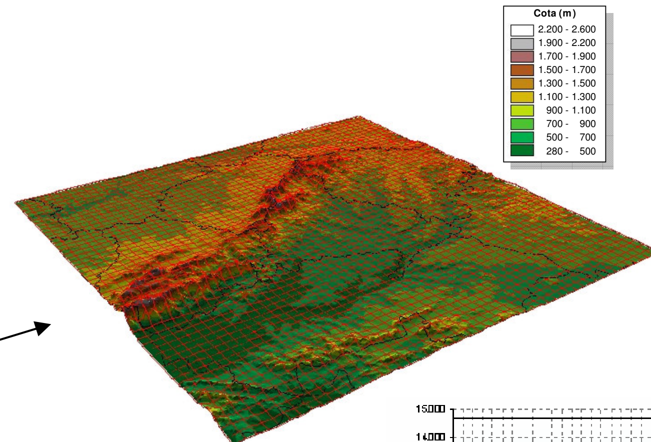
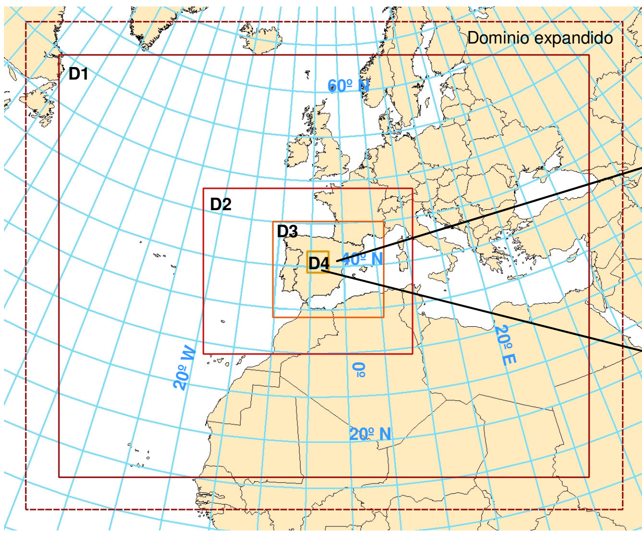
THE SIMCA PROJECT

Meteorological model and simulation setup

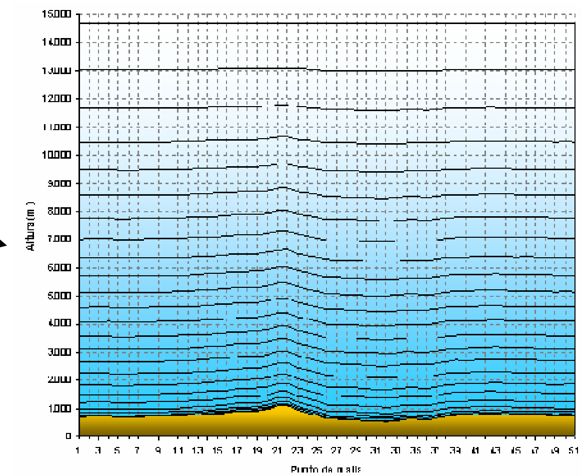
- Pennsylvania State University (PSU) and the National Center for Atmospheric Research (NCAR) mesoscale model (**MM5** V3.6)



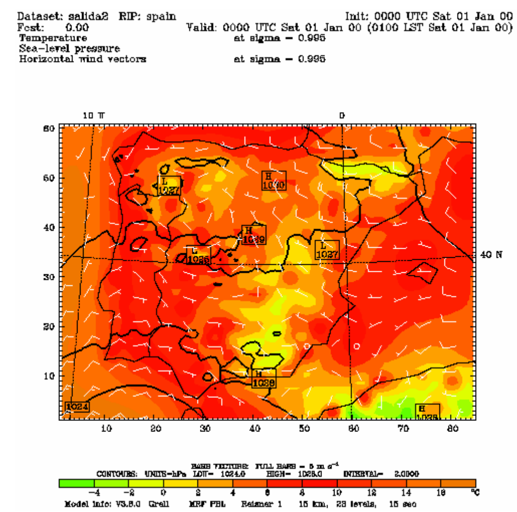
DEM of the finest nested domain (5 km resolution)



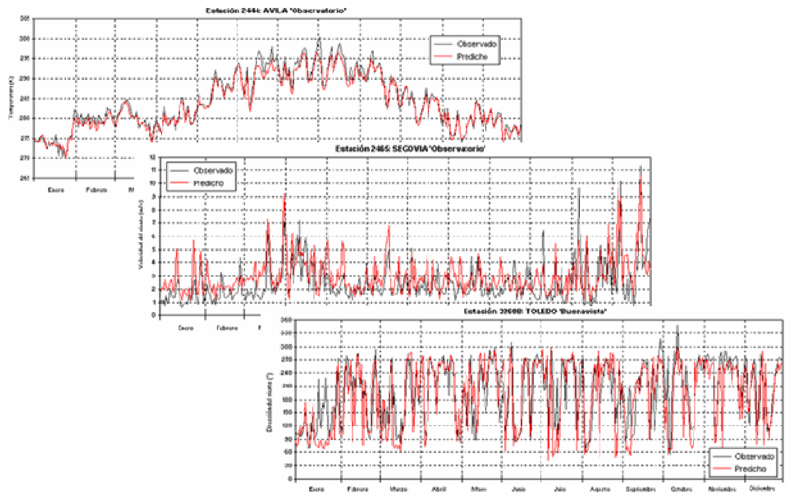
4 nested domains (from 135 to 5 km horizontal resolution)



25 vertical levels (sigma)

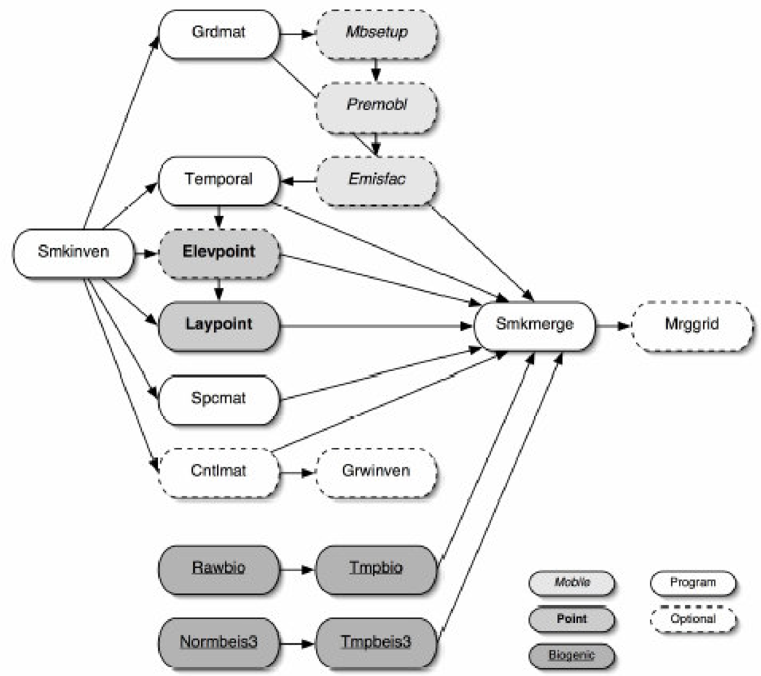


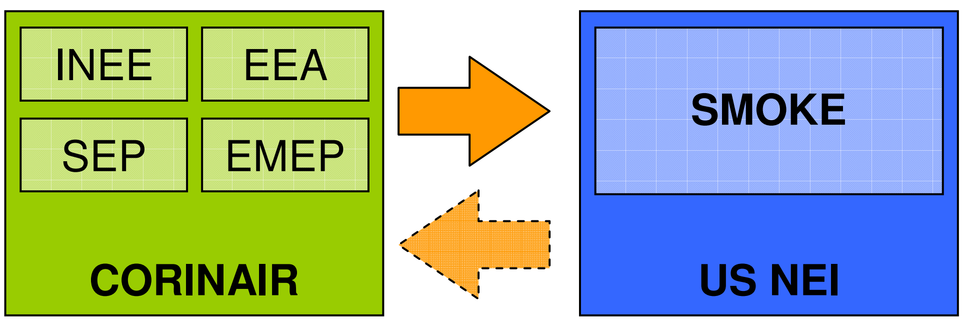
- year 2000 (hourly resolution)
- IC & BC from NCEP global reanalysis
- four-dimensional variational analysis
- optimized parameterizations and physic options for AQ modelling purposes
- results nudging (FDDA)
- satisfactory statistical evaluation



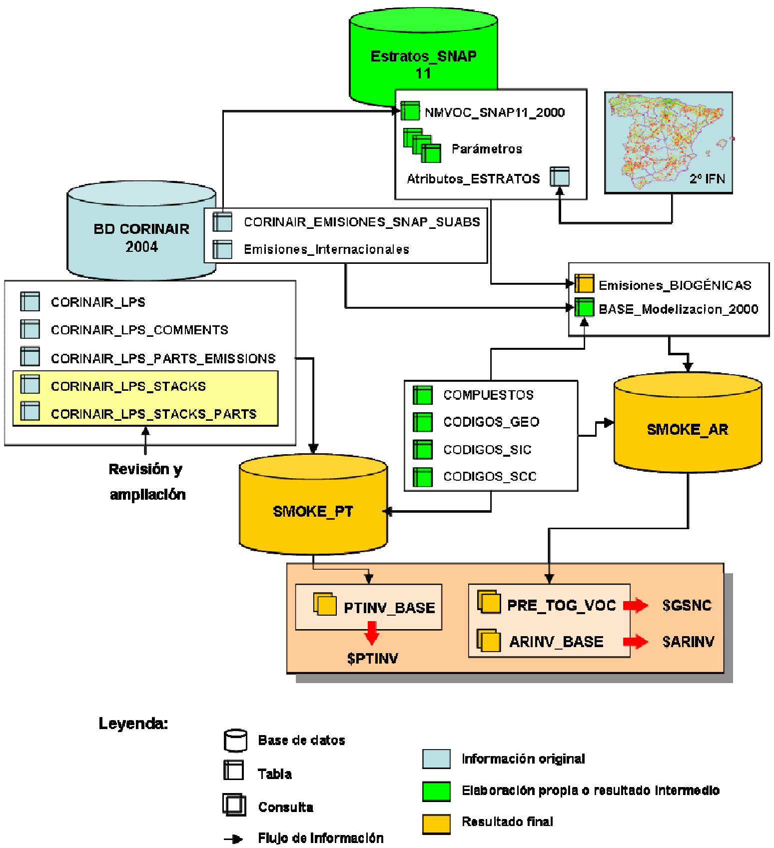
Emission databases and preparation for modelling

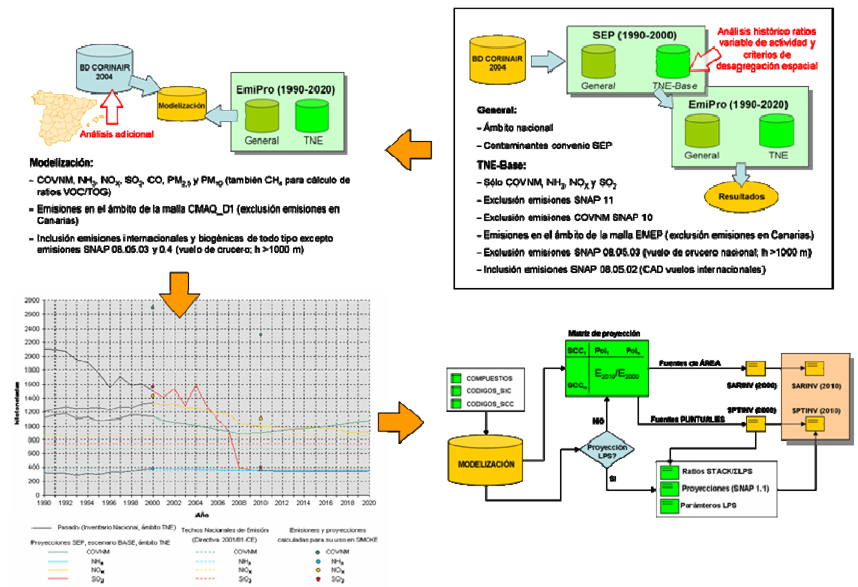
- Adaptation of the MCNC (Media Center of North Carolina) and US EPA (Environmental Protection Agency) Sparse Matrix Operator Kernel Emissions (**SMOKE**) system (V2.1) to the CORINAR methodology





- Emissions from the Spanish National Inventory and SEP project (SNAP-3 resolution)

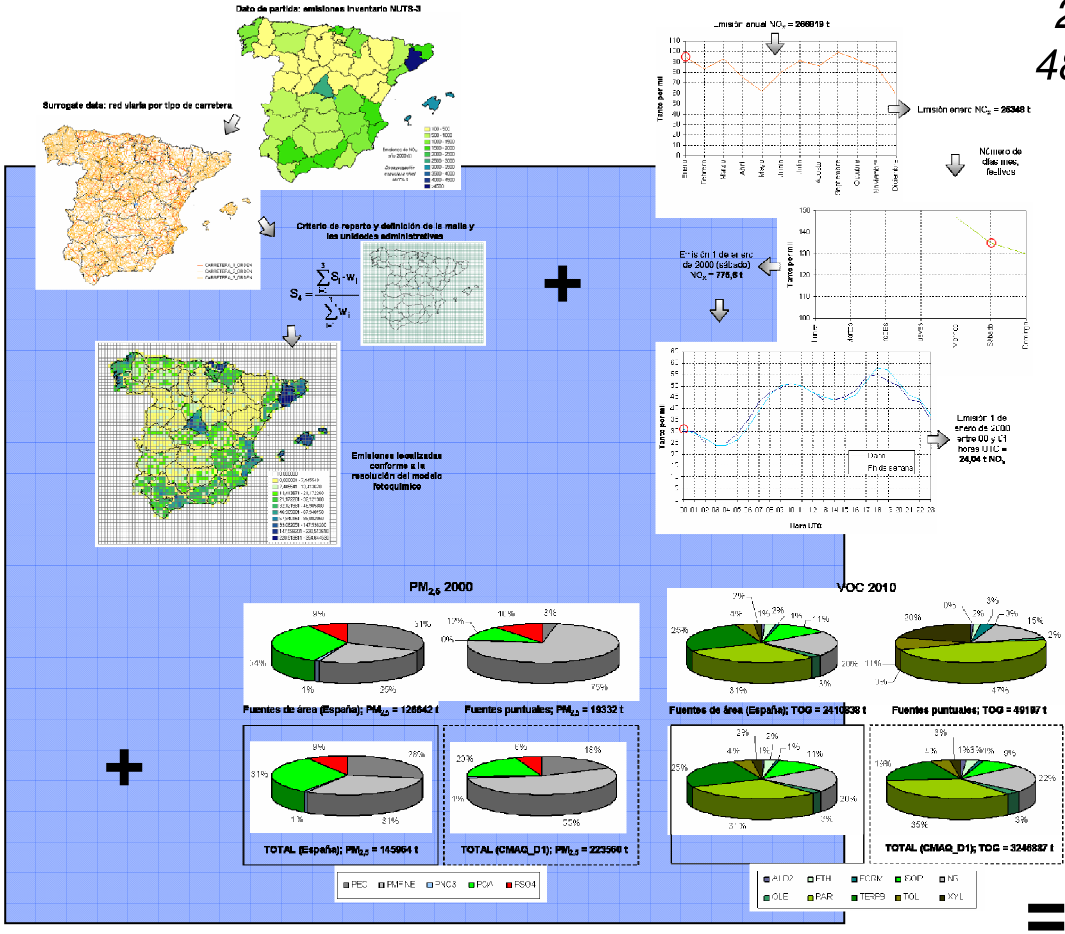




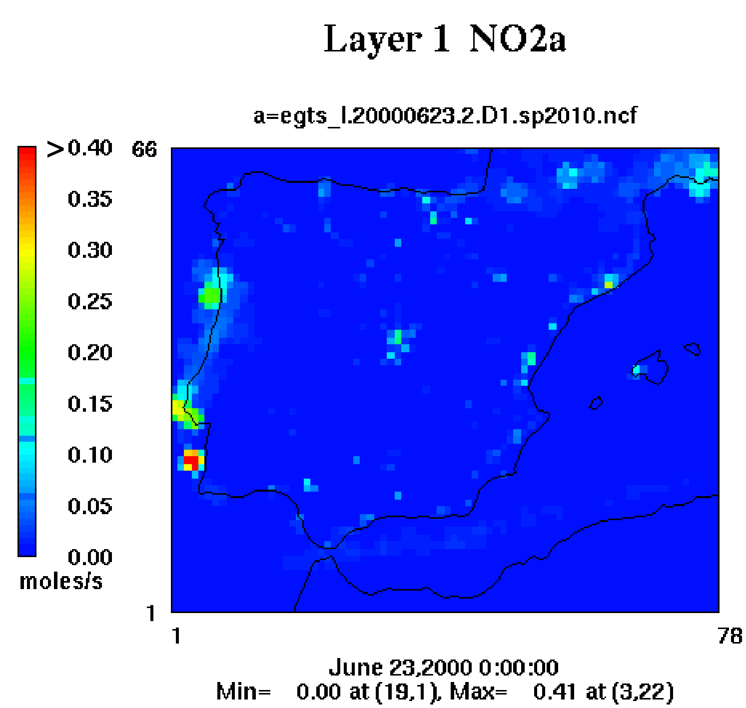
- EMEP estimates for non-Spanish emissions (Portugal and France)

26 surrogate dataset for each domain

Temporal profiles:
208 monthly
48 weekly and
212 diurnal



+ NetCDF I/O API =



Specific CB-4 chemical profiles:

87 for VOCs and 54 for $PM_{2,5}$

Transport-chemical model

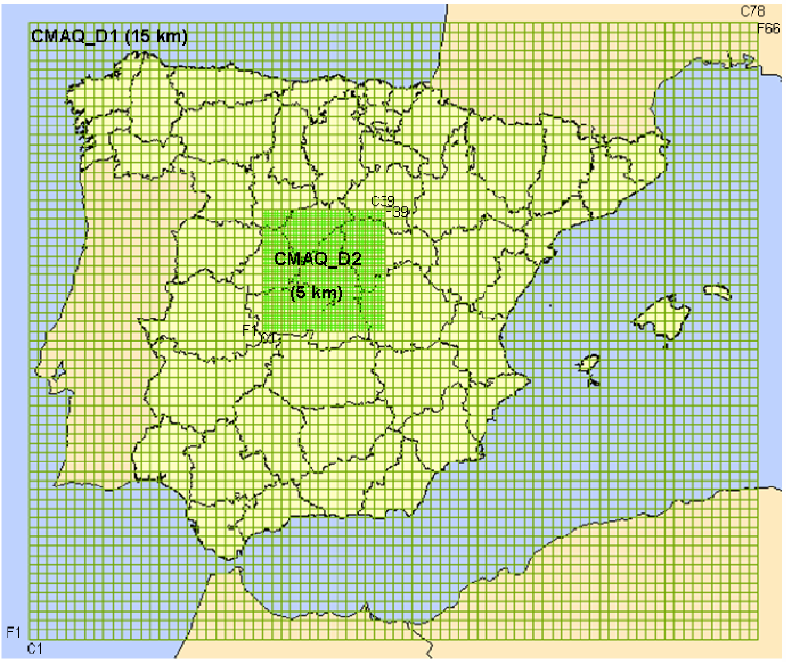
- US EPA Community Multiscale Air Quality (CMAQ) modelling system (V4.4)

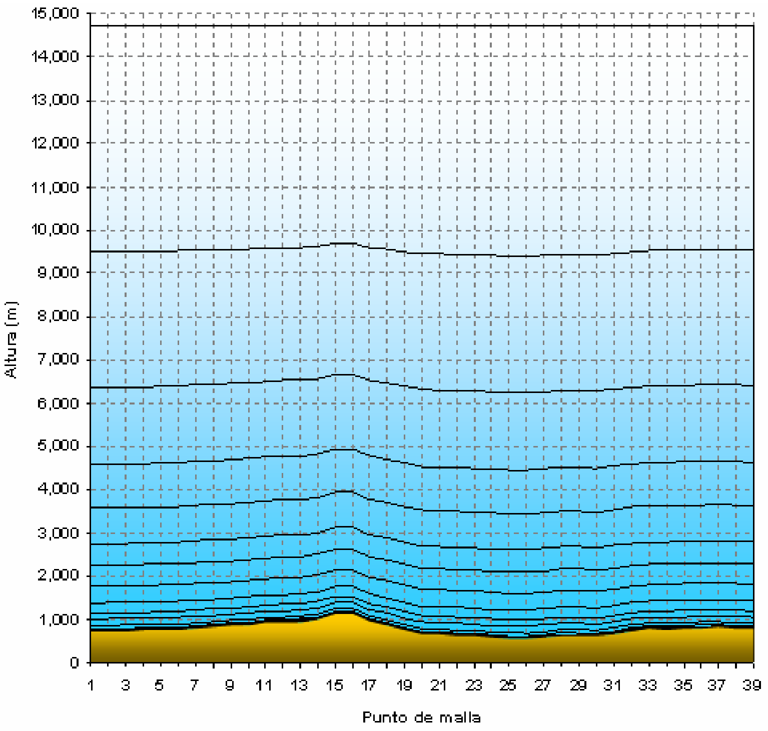
  - “one atmosphere” approach

  - comprehensive urban-to-regional scale Eulerian photochemical air quality process model

  - assessments of multiple pollutants including O_3 and other oxidants, aerosols, and acid/nutrient deposition to ecosystems

- year 2000 and 2010 runs (same meteorology = year 2000)
- emission projections from SEP baseline scenario
- 2 nested domains (15 and 5 km spatial resolution)



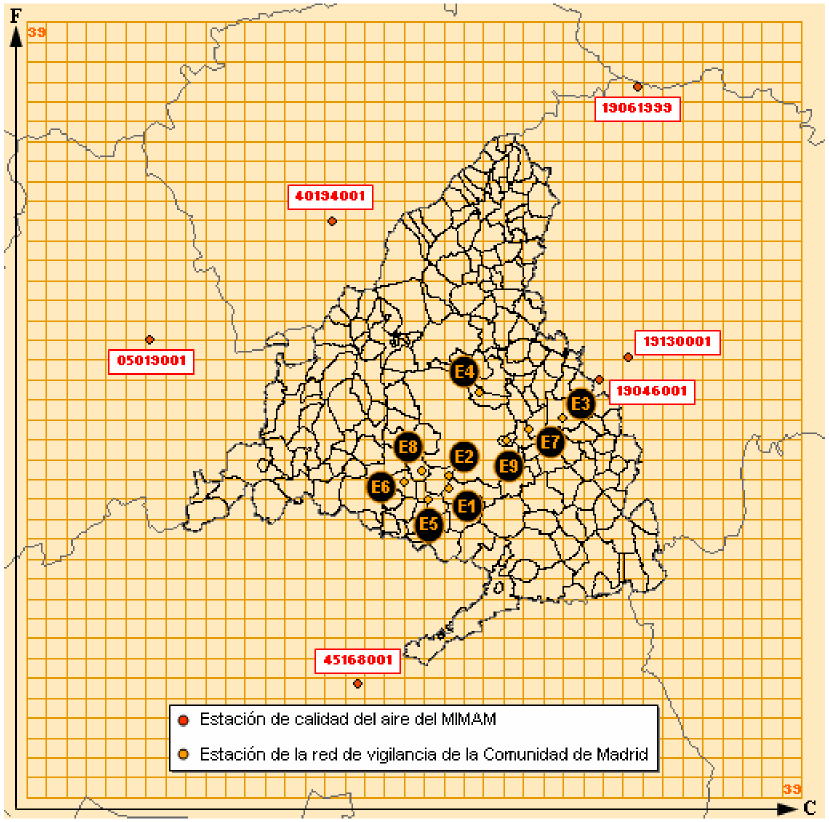


- CCTM options have been selected taking into account previous O_3 simulation references, available information (chemistry) and computational constraints

Process / option	Method / scheme
Advection	Piecewise Parabolic Method (PPM) scheme
Turbulent mixing	K-theory with PBL similarity method for K_{zz}. Crank-Nicholson scheme
Gas-Phase Chemistry	Carbon Bond (CB4_AE3_AQ)
Chemistry Solver	Euler Backward Iterative (EBI)
Aqueous-Phase Chemistry	Regional acid deposition model (RADM)
Dry deposition	Resistance transfer approach
Wet deposition	Henry's law equilibrium for gases
Aerosol dynamics and chemistry	Three-mode distribution. ISORROPIA thermodynamic equilibrium. AE3

Evaluation summary

- The evaluation was carried out using two different datasets:
  - observations from the Ministry of Environment (MIMAM) network stations in D4 (########)
  - observations from the Greater Madrid Area (CAM) air quality monitoring network (E#)



- Variety of station types; from traffic to rural background

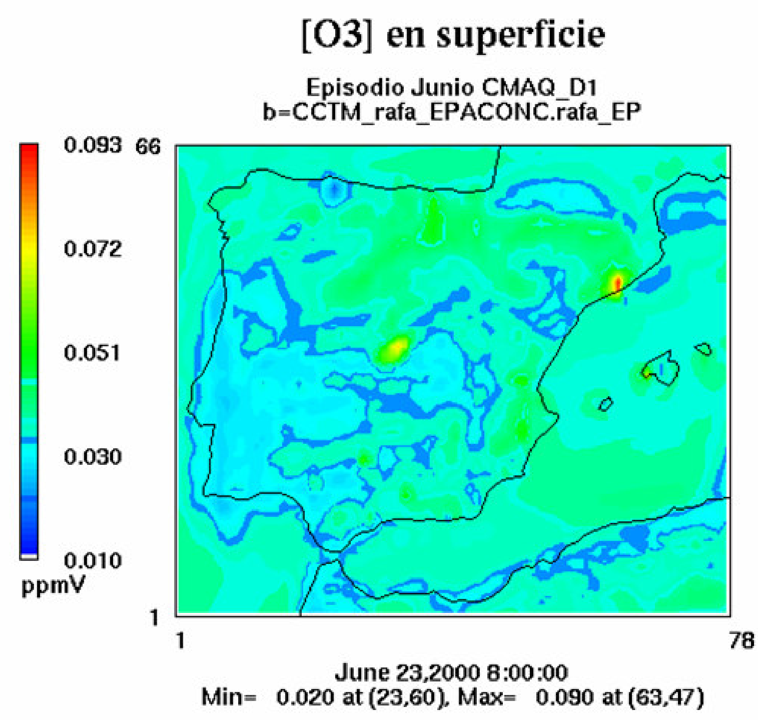
- Simple statistical evaluation

Statistic	Range
MNBE	± (5 – 15) %
MNGE	30 – 35 %
UPA	± (15 – 20) %

EPA suggested benchmarks

$$\text{MNBE} = \frac{1}{IJ}\sum_{j=1}^{J}\sum_{i=1}^{I}\left(\frac{P_j^i - O_j^i}{O_j^i}\right)100$$

$$\text{MNGE} = \frac{1}{IJ}\sum_{j=1}^{J}\sum_{i=1}^{I}\left(\frac{\left|P_j^i - O_j^i\right|}{O_j^i}\right)100$$



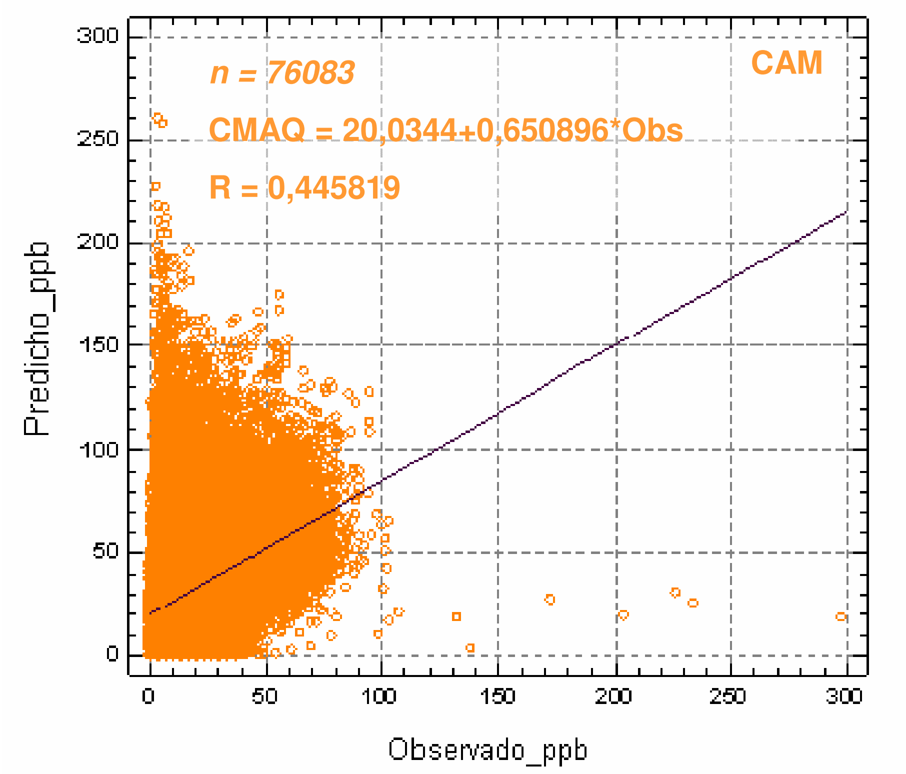
- Aggregated results by season and network

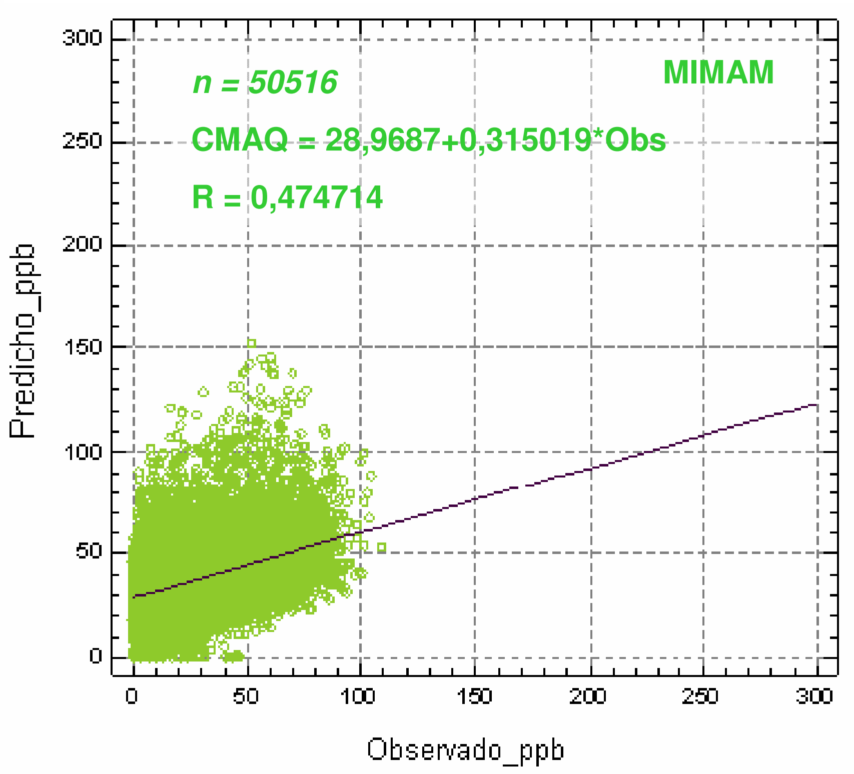
Period	Network	MNBE	MNGE	UPA
Winter	CAM	5	23	50
	MIMAM	-2	14	47
Spring	CAM	13	29	-67*
	MIMAM	-2	17	38
Summer	CAM	-2	28	61
	MIMAM	-22	25	-4
Autumn	CAM	21	36	81
	MIMAM	-5	16	4
TOTAL	**CAM**	**4**	**28**	**-67**
	MIMAM	**-11**	**20**	**38**

* During the 29th of April 2000 extraordinary high values were recorded in some points of the CAM network. The maximum O_3 hourly concentration (Fuenlabrada station) was 1133 µg/m^3 (538 ppb)

- Model performs sensibly well overall
- UPA generally outside the suggested range (seasonal evaluation)
- The model tends to overestimate O_3 concentrations inside the GMA, while outside this region, the tendency is to underestimate
- This information is not enough to get an accurate description of model performance

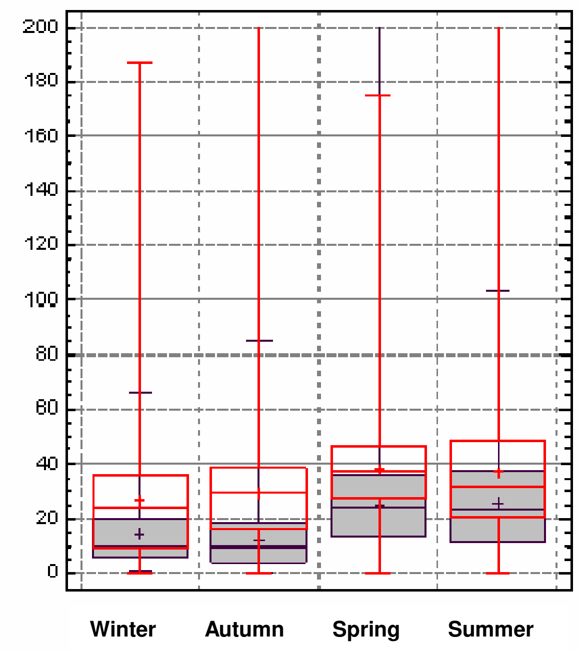
- Different kinds of graphic comparisons can help to get a better picture



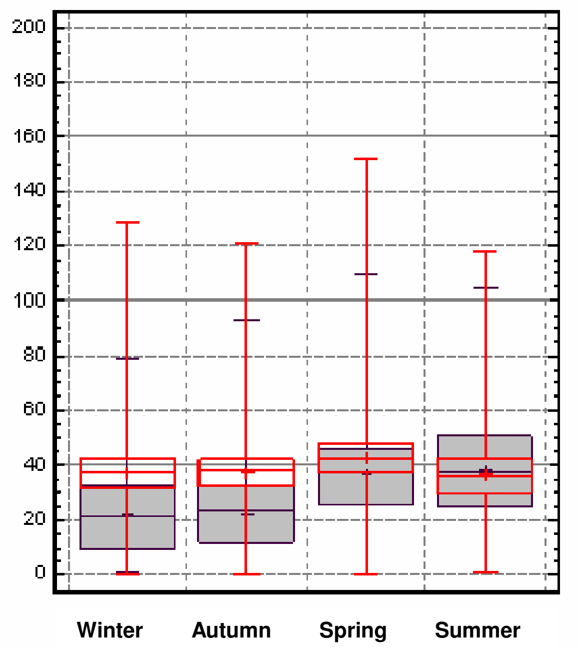


- Predicted extreme values are more often in the CAM (traffic?)
- Acceptable correlation coefficients for this kind of application

CAM stations



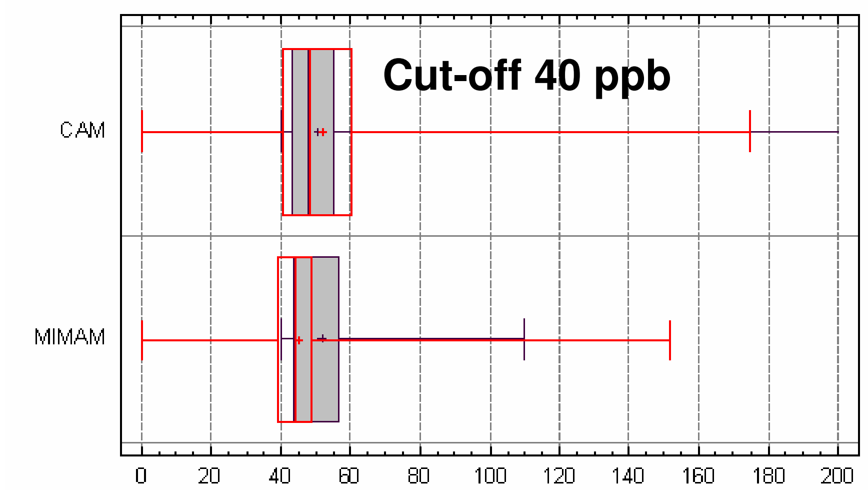
MIMAM stations



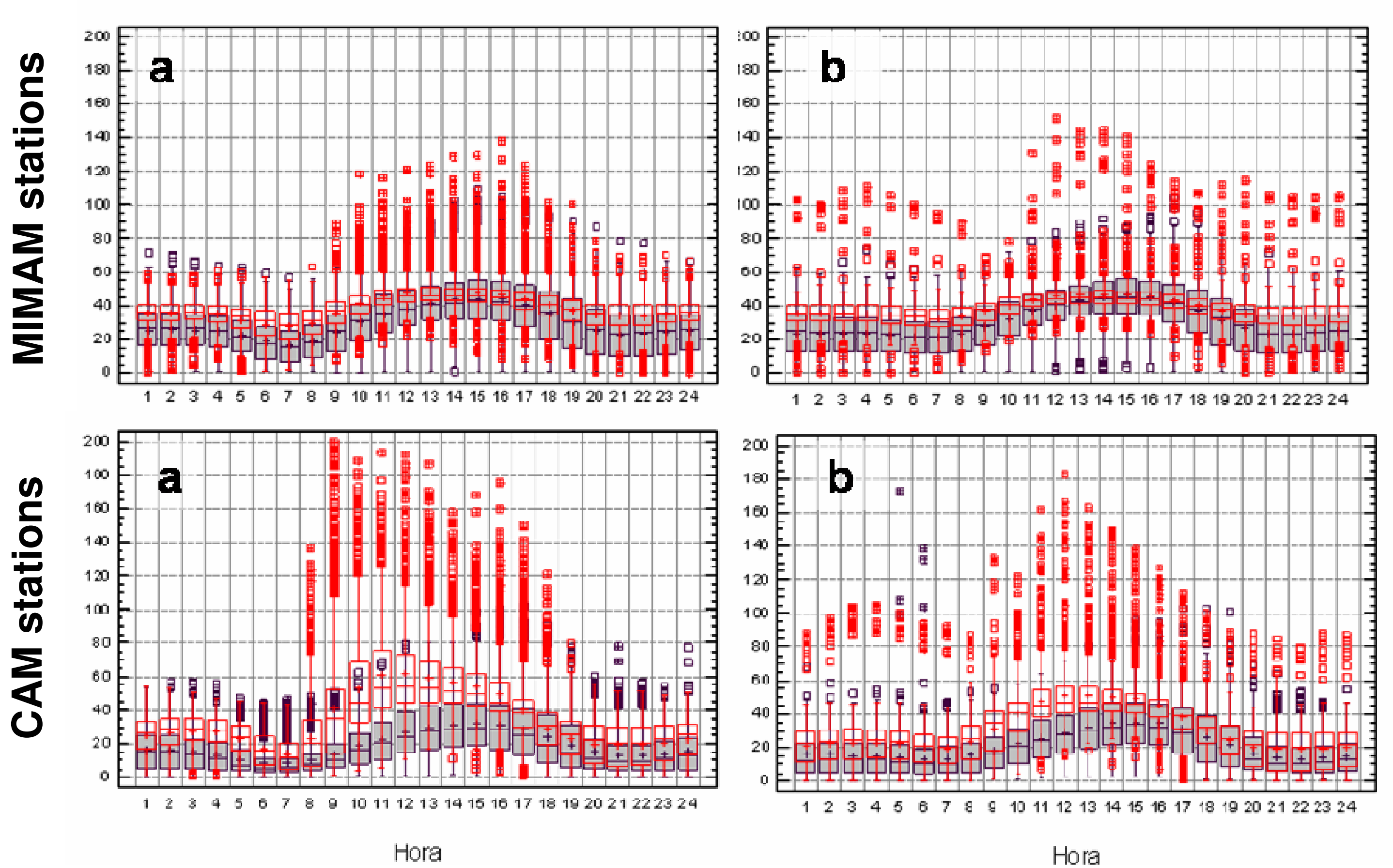
Observed values

Predicted values

- Larger dispersion in forecasted values in the CAM
- For both observed and predicted seasonal averages, spring gives the highest value



- The model is able to depict typical ozone cycles, but there is a large spread of error magnitude depending on the stations

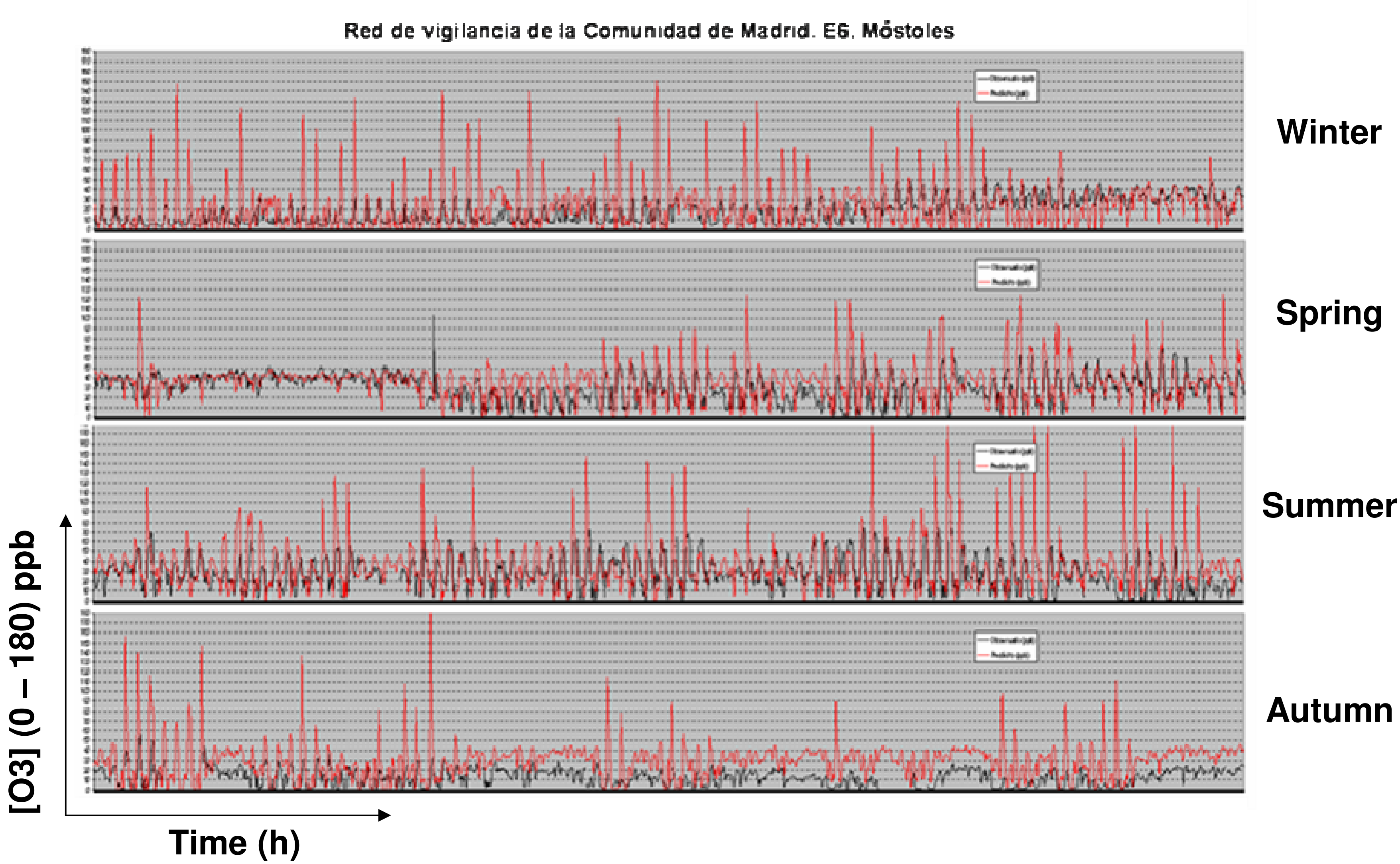


a - weekday

b – weekend

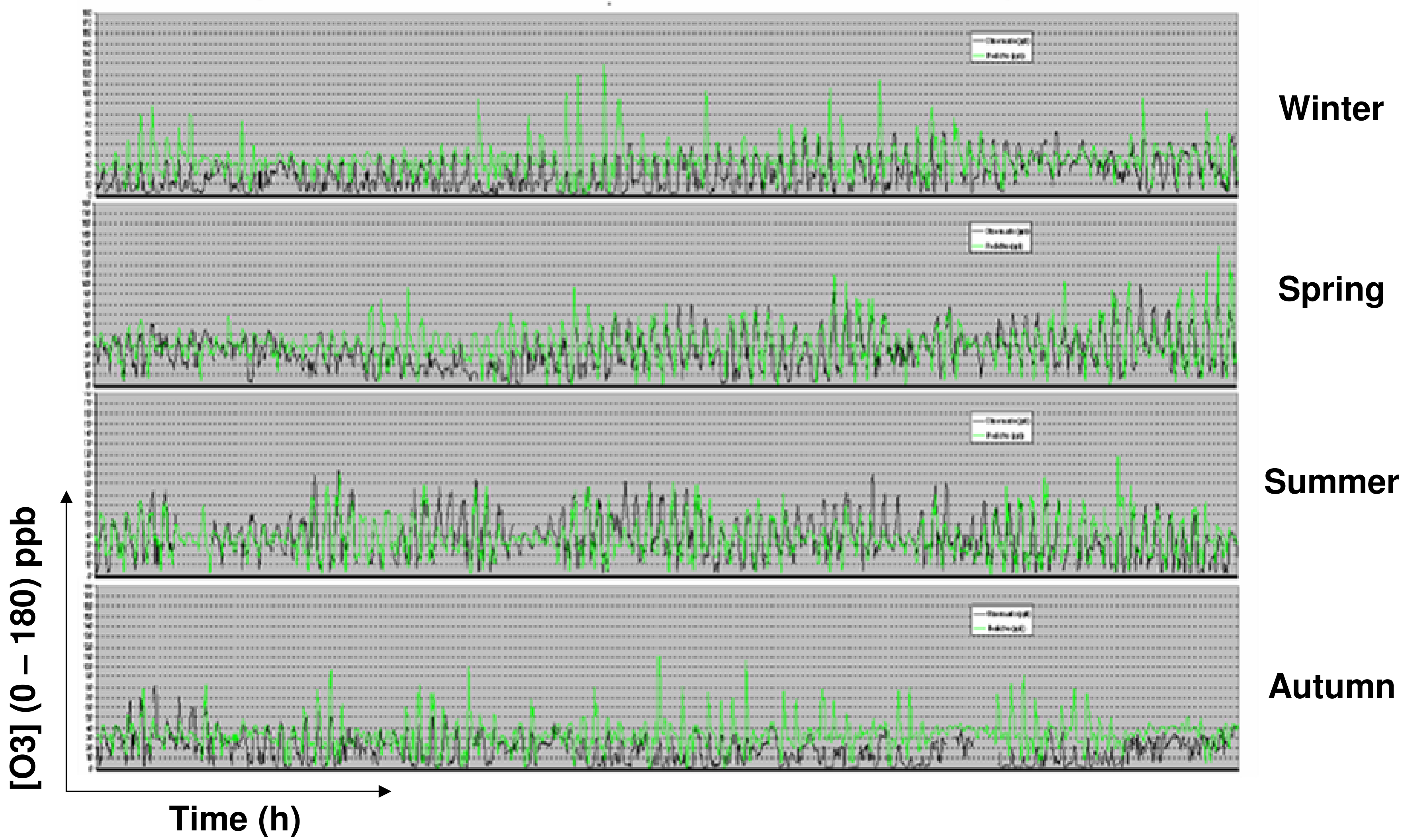
- Average hourly disagreement varies notably from weekdays to weekends in the CAM stations (road traffic?)

- Analysis results at station level reveals interesting issues



Annual hourly values comparison observed (black) Vs predicted (red)

Red de vigilancia de la Comunidad de Castilla La Mancha. Estación 19046001. Azuqueca de Henares



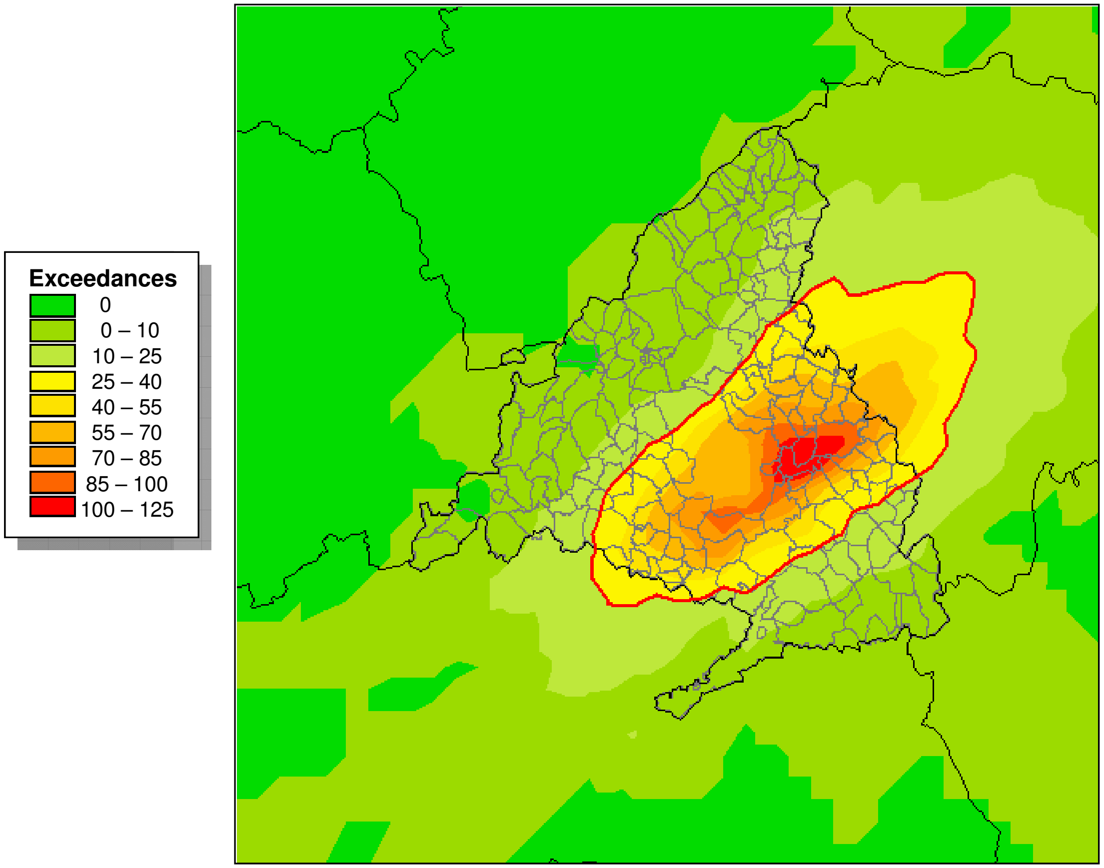
Annual hourly values comparison observed (black) Vs predicted (green)

- CMAQ ground-level ozone predictions are acceptably good overall, although the performance varies widely depending on the location and period of the year
- at certain times when observed concentrations were very low, the model shows a tendency to overestimate hourly values in urban locations of the Greater Madrid Area
- the uncertainty of O_3 measurements is unknown and may be relevant
- Unrealistic urban road traffic emissions estimates*, chemical speciation or spatial/temporal allocation could be the main source of error

* Traffic emissions in the SNEI depend on global energy balances according to official statistics. NUTS3-level fuel consumption may be misestimated in the Inventory

Results

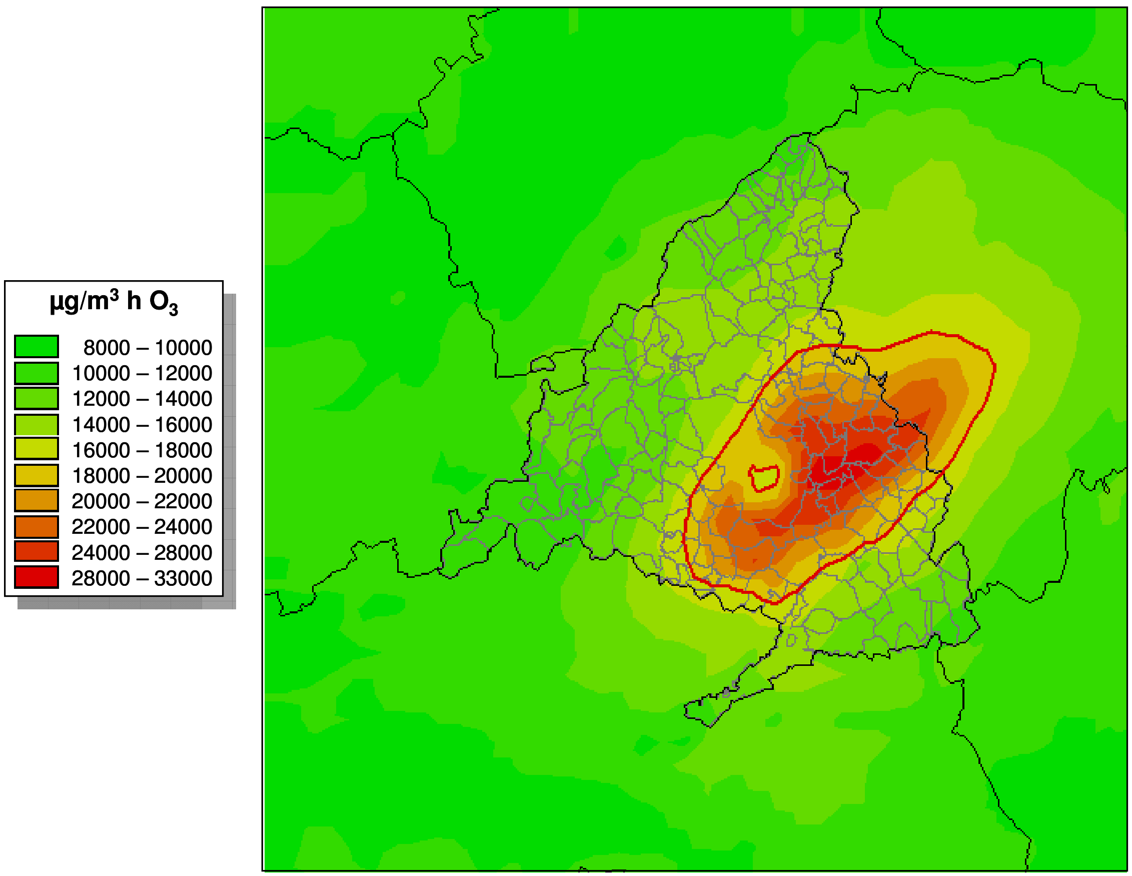
- Assessment of the fulfillment of the 2002/3/EC Directive in the Greater Madrid Area (GMA)



Maximum daily 8-hour mean < 120 µg/m3 not to be exceeded on more than 25 days per calendar year

Target values for the protection of human health

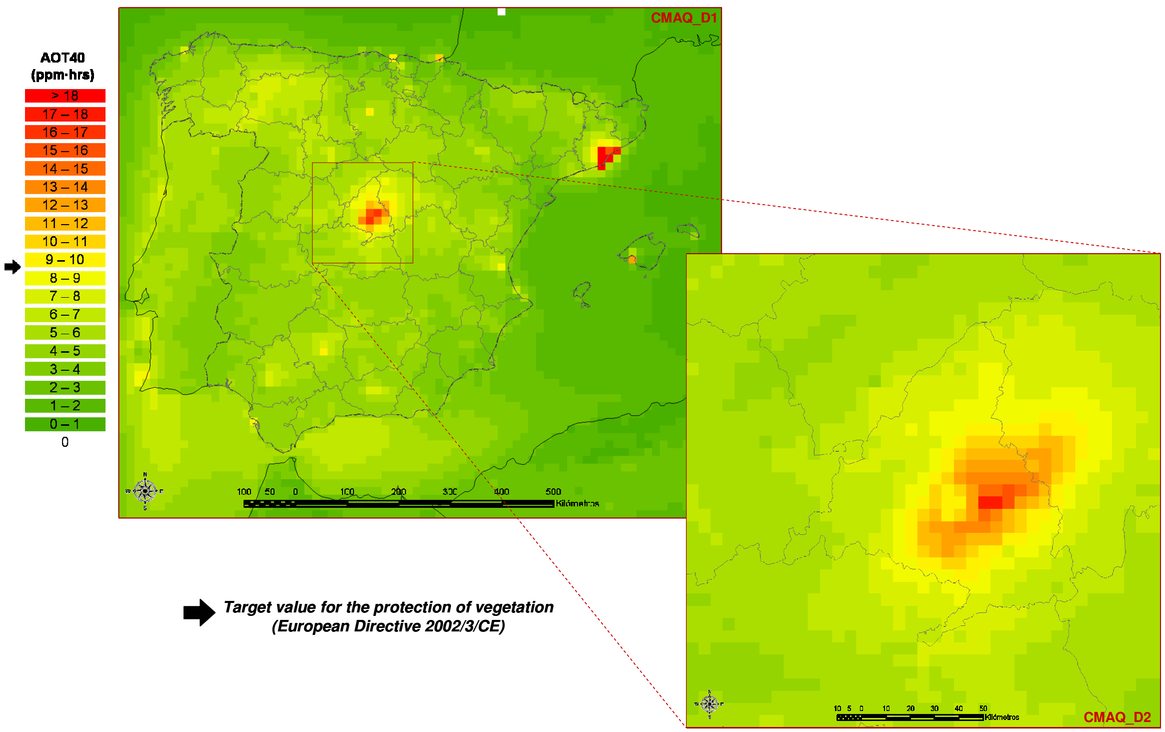
- Assessment of the fulfillment of the 2002/3/EC Directive in the Greater Madrid Area (GMA)

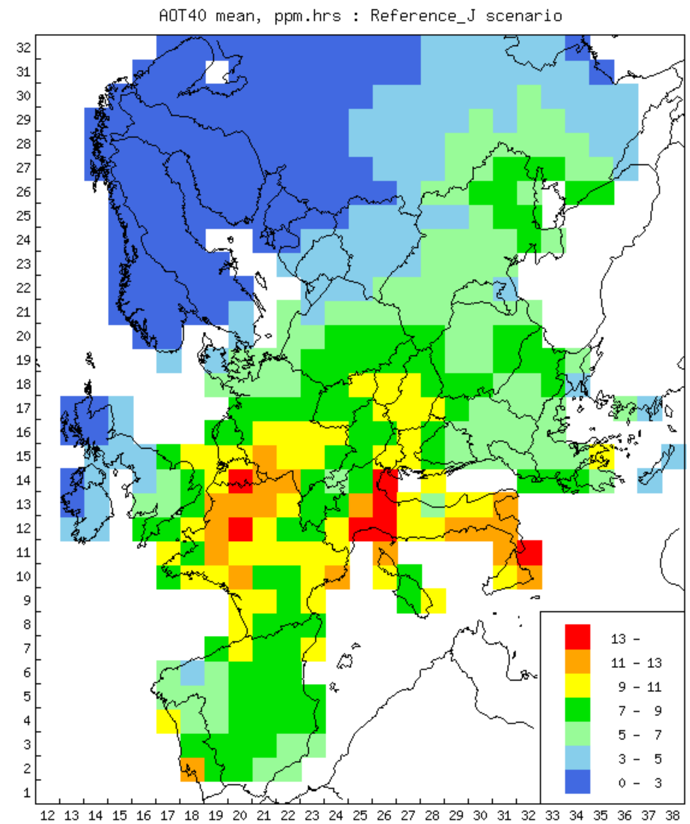


AOT40 calculated from 1h values from May to July < 18000 µg/m^3·h

Target values for the protection of vegetation

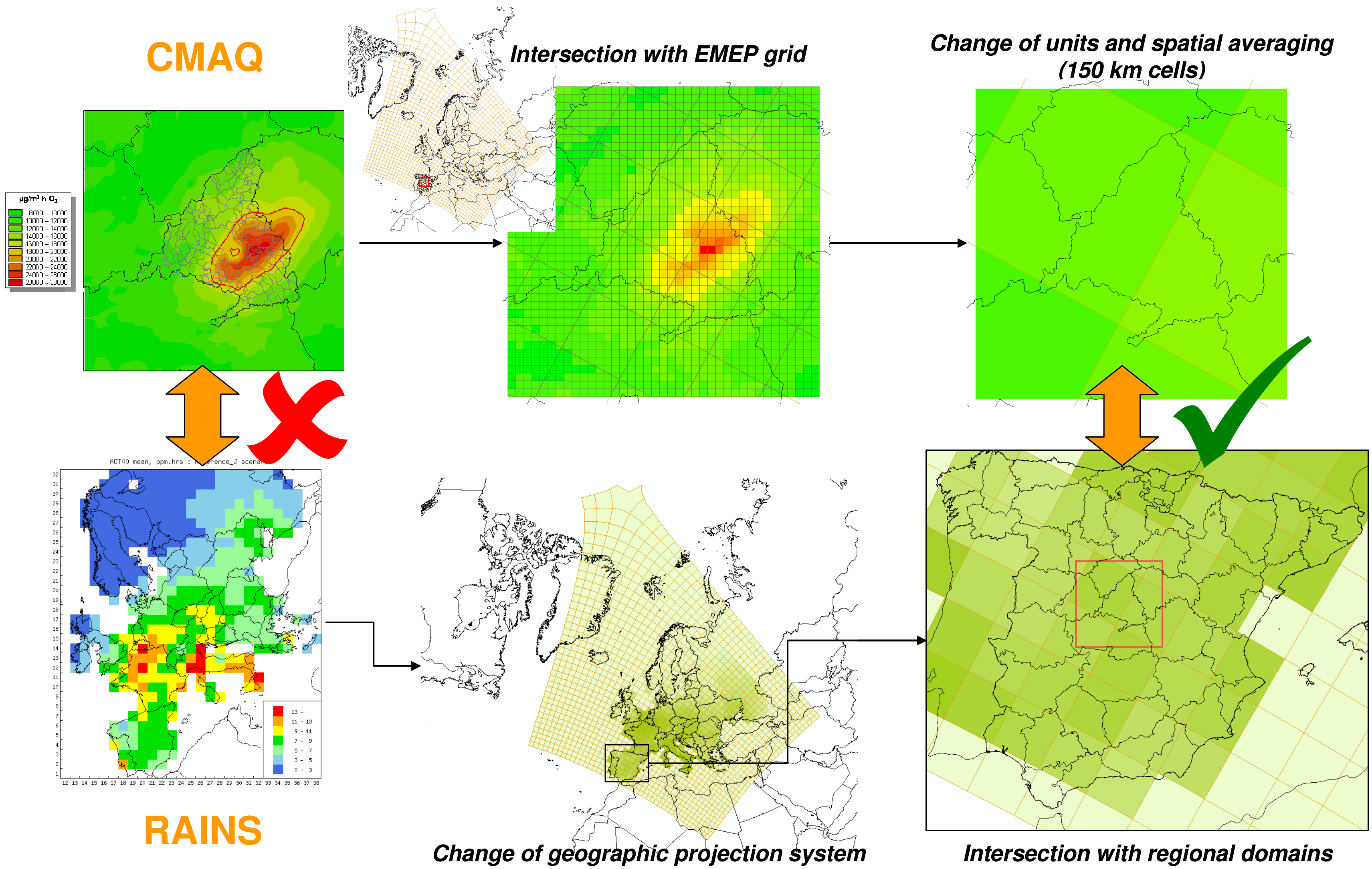
- Comparison with EMEP-RAINS (AOT40)



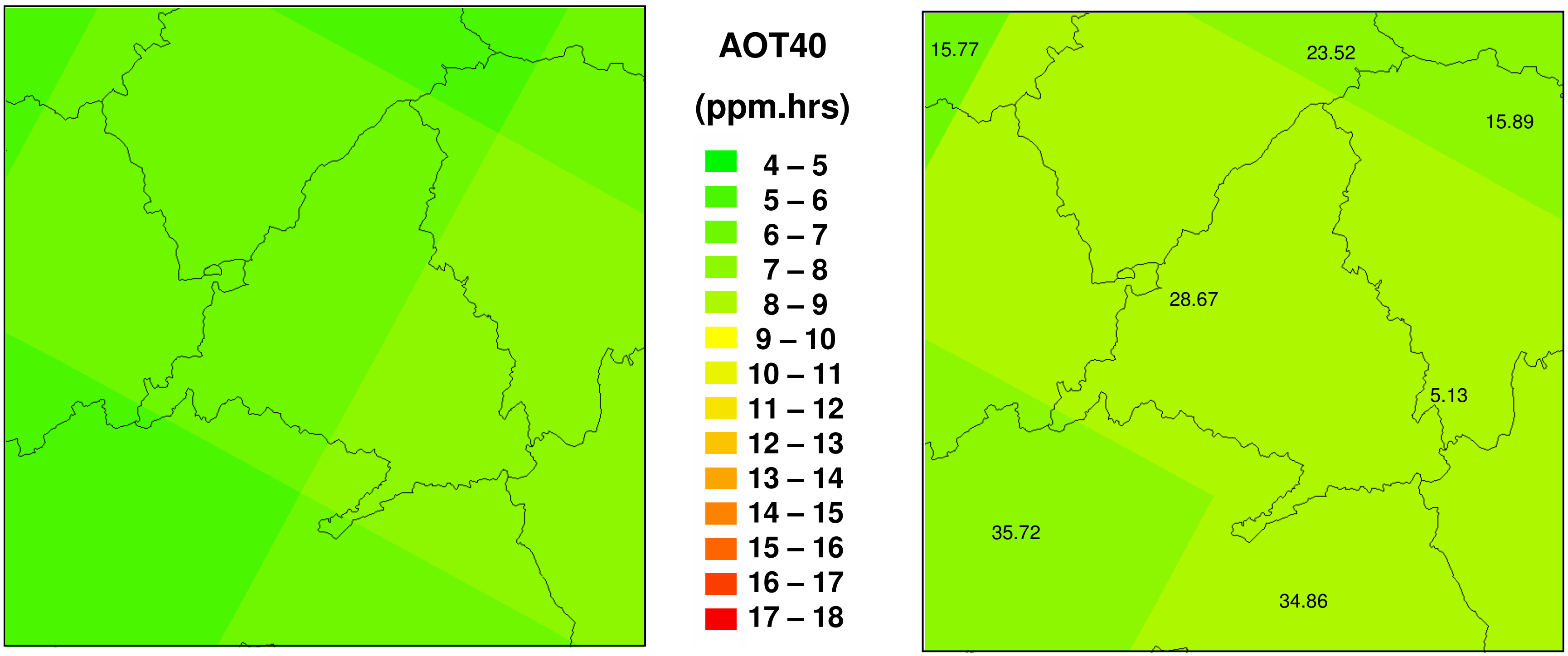


National (regional) modelling results ? RAINS (150 km) modelling results

- Reduction to a common basis



Model performance

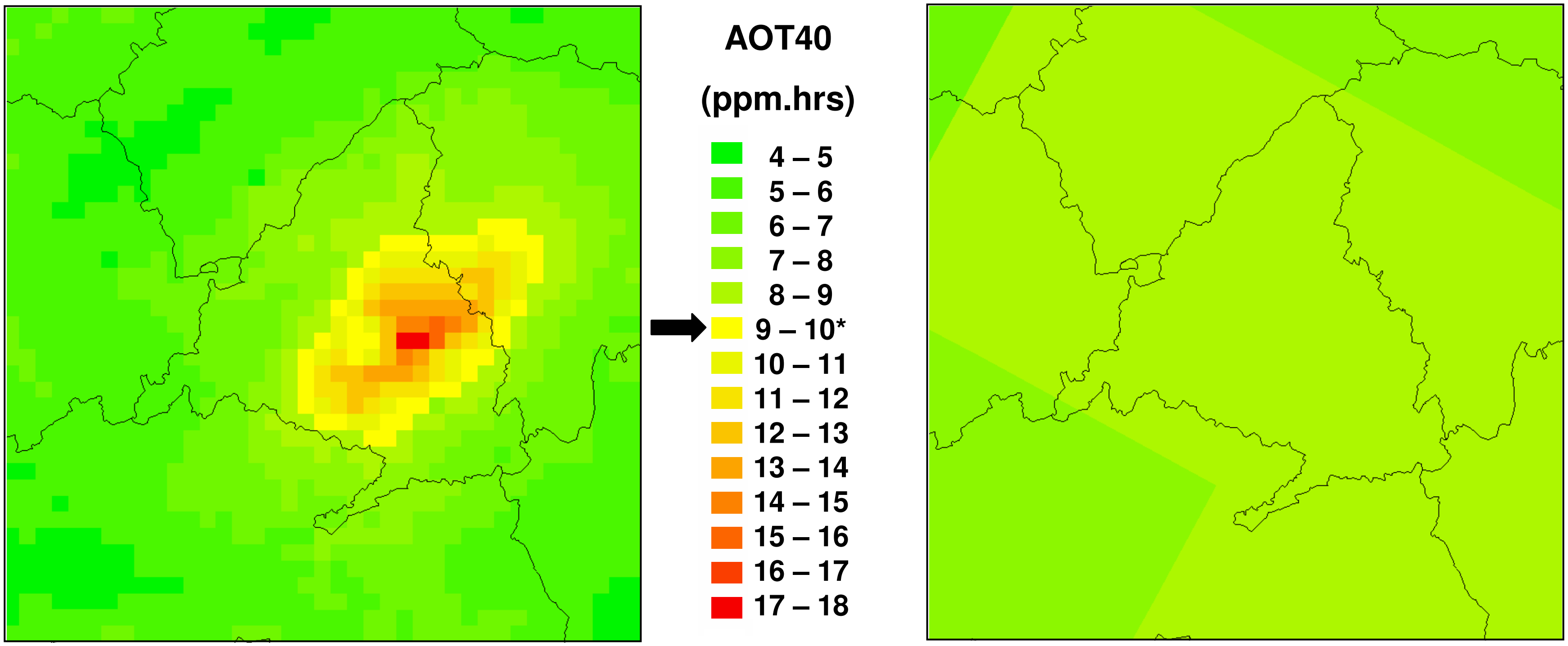


CMAQ RAINS

Mean normalized Bias: 22.46%

- Reasonable agreement

Reference scale limitations



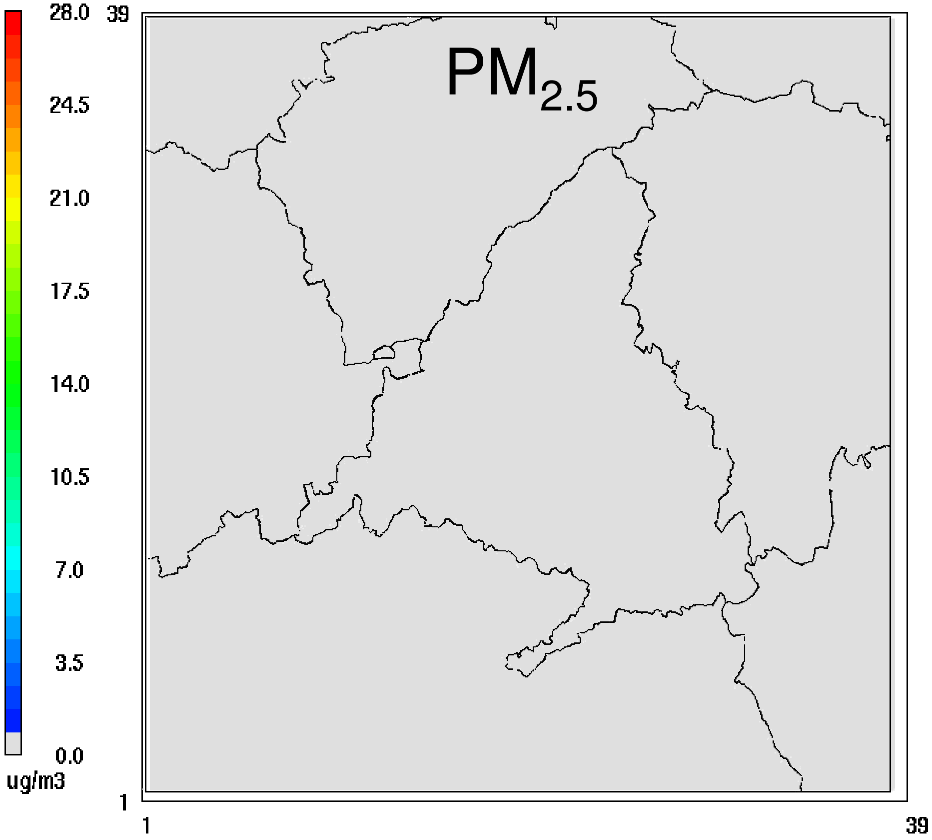
CMAQ RAINS

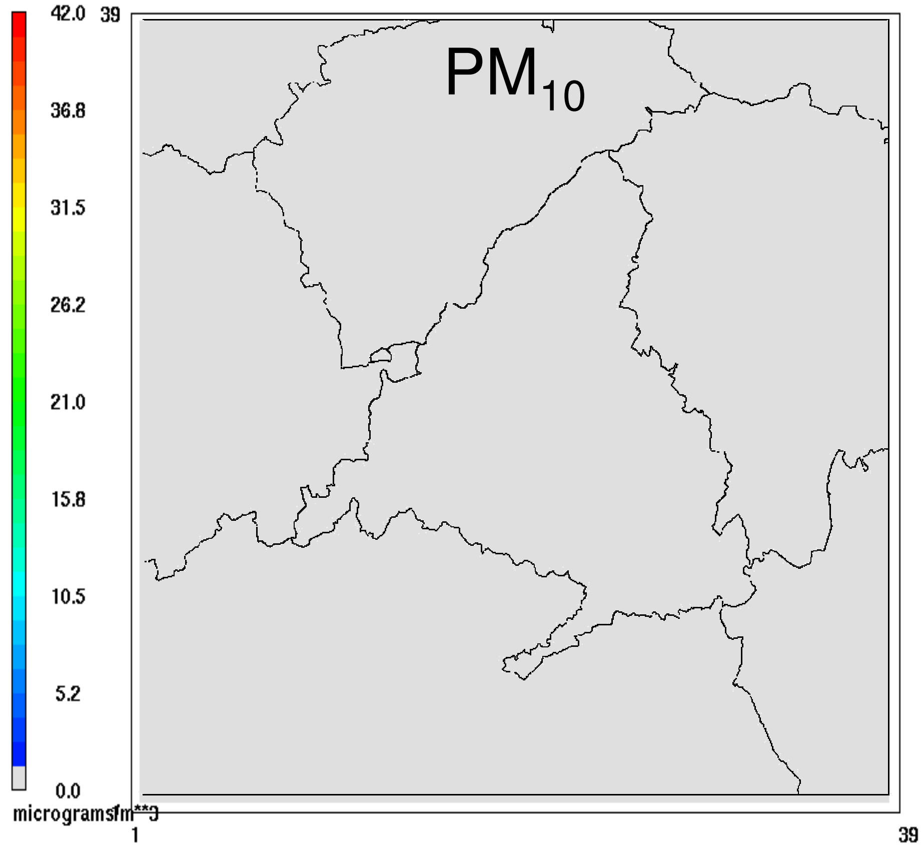
** 9 ppm.hrs ≈ 18000 μg m^{-3} hrs*

(Target value for the protection of Vegetation. Directive 2002/3/EC)

- It is not feasible to reproduce some (important) regional issues for low spatial resolution (150 km, 50 km)

- Preliminary PM simulations (GMA)





- Some emission sources are missing, re-suspension and long-range transport not considered, but still underestimations are too large

Some lessons learned so far

- The MM5-SMOKE-CMAQ modelling system can be used as a part of an integrated assessment modelling system, useful to policy assessment and decision-making support in Spain
- The development of a formal sensitivity and uncertainty analysis considering all the inputs and components of the system is needed:
  - input data (meteorology, <u>emissions</u>, etc.)
  - model formulation and setup
  - meteorological and air quality monitoring data

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- SIMCA is a 3-year research project funded by the Spanish Ministry of Environment

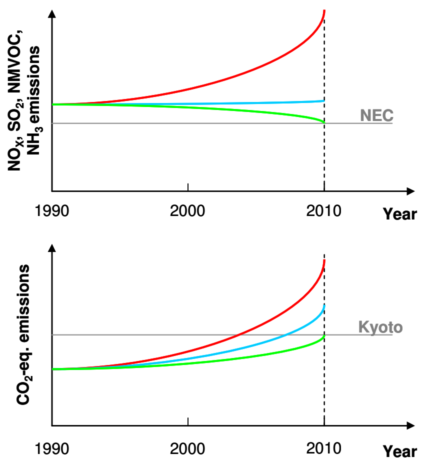
- Same basic objectives and methodology:

  - intended to provide a comprehensive air quality system to support environmental decision making process, providing a platform for emission strategy analysis and planning assessment in the Iberian Peninsula (IP)

  - Major upgrades and improvements

- 1-km spatial resolution for the whole IP
- Non-deterministic approach: future-year runs based on 6 meteorological years (2000-2005)
- Refined initial and boundary conditions for the WRF model (1º AVN reanalysis, 3D-VAR)
- AQ IC&BC from global models (GEOS-CHEM, EMEP)
- Improvement of emission (SNAEI and SEP) processing:
  - spatial allocation (surrogate data)
  - temporal allocation (temporal patterns)
  - chemical speciation (VOCs, NO_X, PM fine)

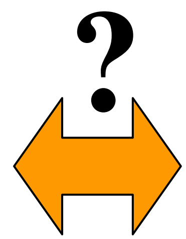
- Extended scenario analysis:
  - -up to 2020 (standard scenarios)



Business As Usual (Tendencial): reference scenario without any measure taking into account the past emission trends.

Baseline (Base): the more likely future situation considering the enacted legislation and adopted plans, measures and policies.

Target (Objetivo): the environmental objectives are reached through additional measures (e.g. good practices, technical improvements, further policies, etc.).



-Achievement of emission ceilings including GHG

- Fulfilment of air quality targets

  - -customized scenarios and P&M (what if?)

- Cost-benefit analysis
- Optimization module
- Links to personal exposure and health impacts

- Model setup based on sensitivity analysis (physics, chemical mechanism, etc.)
- Consistent approach for the Iberian Peninsula (collaboration of the Portuguese Ministry and the UNL)
- CMAQ European-scale simulations to be performed on a regular basis
- Consistent result comparison with EMEP-RAINS (and other models…)
- Extended model performance evaluation (primary pollutants, $PM_{2.5}$)

Thank you for your attention!

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