Italian National Agency for New Technologies, Energy and Sustainable Economic Development

EVALUATION OF SEVEN CHEMISTRY TRANSPORT MODELS IN THE FRAMEWORK OF EURODELTA III INTERCOMPARISON EXERCISE

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EuroDelta III

EuroDelta exercise contributes to the scientific work of TFMM (Task Force on Measurement and Modelling)

TFMM was established by the Executive Body of EMEP (European Monitoring and Evaluation Programme) in 2000 to offer a forum to the Parties, the EMEP centres and other international organizations:

- to discuss and evaluate measurements and modelling and
- to further develop working methods and tools.

It also supports the implementation of the protocols of the UNECE (United Nations Economic Commission for Europe) convention CLRTAP (Convention on Long Range Transboundary Air Pollution) such as: Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone, protocols for heavy metals (HM) and persistent organic pollutants (POPs) in Europe. This Task Force is led by France, World Meteorological Organization (WMO) co-chairs its meetings.

EuroDelta III

EURODELTA III project: part A started in 2012 and part B in 2014

EURODELTA III Part A (campaigns): was designed to exploit and interpret intensive measurement campaigns carried out by EMEP.
Bertrand Bessagnet

EURODELTA III Part B (trends): aims to assess the efficiency of air pollution mitigation strategies over the past 20 years; it aims to support the Convention on Long Range Transport of Air Pollutant, in assessing the benefit of its main policy instrument: the Gothenburg protocol, agreed upon in 1999 with a reference year in 1990.
Augustin Collette

EuroDelta history

EURODELTA I (2004) examined the common performance of the models in predicting 2000 and 2020 air quality in Europe using the concept of a model ensemble to measure robustness of predictions. The spread of predictions about the ensemble gave a measure of uncertainty for each predicted value.

EURODELTA II (2006) investigated how the different models represent the effect on pollutant impacts on a European scale of applying emission reductions to individual emission sectors.

EuroDelta III – Part A: campaigns

Bertrand Bessagnet

Teams	Models with references	Model acronym in this study	Simulated periods
PSI/RSE	CAMx (ENVIRON, 2011)	CAMx	2006, 2007, 2008, 2009
INERIS	CHIMERE (Menut et al., 2013)	CHIM	2006, 2007, 2008, 2009
HZG	CMAQ (Byun and Schere, 2006; Matthias et al., 2008)	CMAQ	2006, 2007, 2008, 2009
MSC-W – Met.NO	EMEP (Simpson et al., 2012)	EMEP	2006, 2007, 2008, 2009
TNO	LOTOS-EUROS (Sauter et al., 2014)	LOTO	2006, 2007, 2008, 2009
ENEA/ARIANET	MINNI (ARIANET, 2004)	MINNI	2006, 2007, 2008, 2009
FUB	RCG (Stern et al., 2006)	RCG	2008, 2009

EMEP intensive measurement campaigns:

1–30 June 2006

8 January–4 February 2007

17 September–15 October 2008

25 February–26 March 2009

(Bessagnet et al., 2016, Atmos.Chem.Phys.)

Participating institutions

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Setup of simulations

Input data

➢ Anthropogenic emissions:

- TNO 0.125 0.0625 emissions for 2007 from MACC (Kuenen et al., 2011);
- EMEP 0.5 x 0.5 emission inventory for 2009 (Vestreng et al., 2007);
- emission data from the GAINS database (http://gains.iiasa.ac.at/gains).

➢ Fire emissions

- GFASv1.0 database only 2006

➢ Boundary conditions

- reanalysis MACC II project (Modelling Atmospheric Composition and Climate)

➢ Meteorology

-ECMWF IFS (Integrated Forecast System) 0.25 ◦ spatial resolution except CMAQ which used COSMO CLM

Simulation domain:

- the same area with 0.25◦x0.25◦ resolution in longitude and latitude, except CMAQ which used a Lambert-conformal conic projection

Data for model validation:

EMEP operational monitoring data
AirBase data
ACSM data from EUCAARI project

Free model configurations for:

➢land use
➢biogenic VOC emissions
➢sea salt emissions
➢dust emissions
➢NO emissions

How large is the variability among the models?

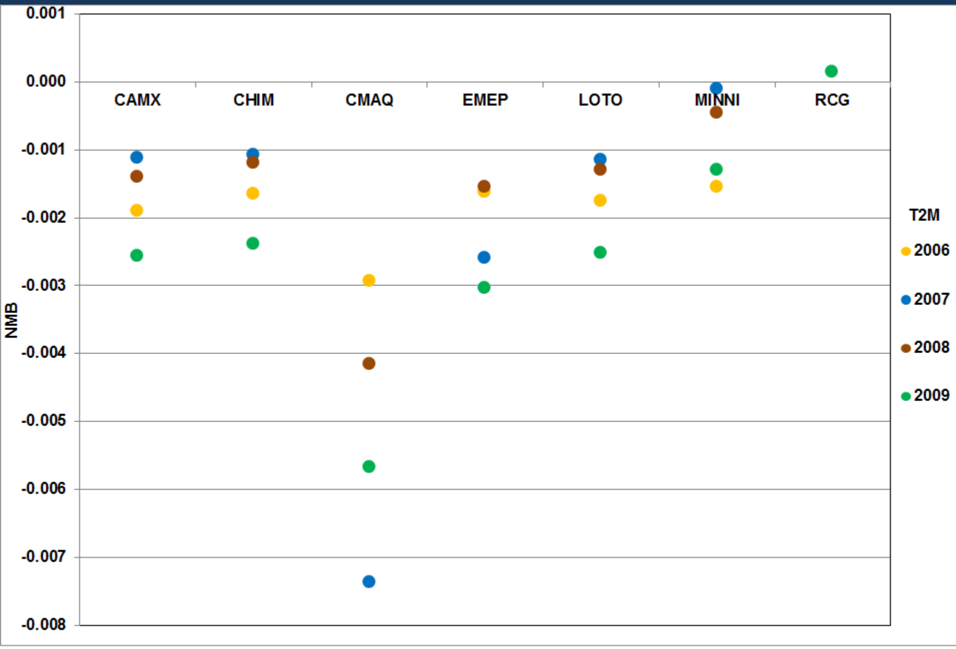
The evaluation was carried out at sites against the observations and was focused on identifying the factor such as meteorology, emissions, model formulation, which is mostly contributing to the differences.

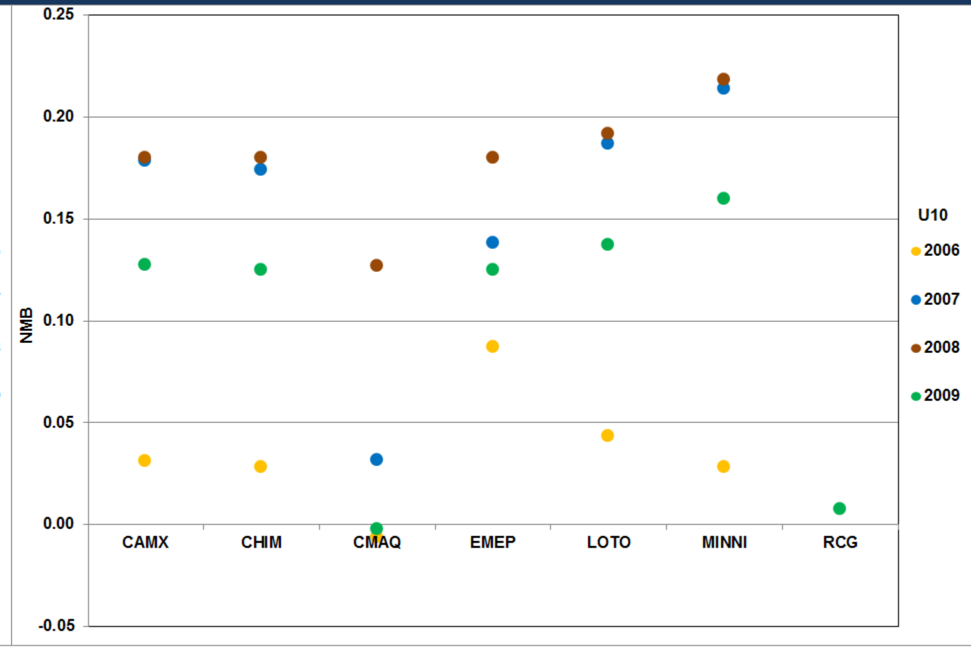
Therefore, the inter-comparison addressed:
-primary pollutant concentrations : elemental carbon (EC)
-secondary pollutant concentrations: ozone (O_3)
-pollutant concentrations with primary and secondary compounds such as organic carbon (OC) and particulate matter (PM10)
-wet deposition of reduced (WNHx) and oxidised (WNOx) nitrogen

Statistical indicators used for inter-comparison :
Normalized mean bias defined as NMB = (M-O)/O , -1 to +∞
Correlation coefficient: $R = \left(\sum_{i=1}^{N} (M_i - \bar{M})(O_i - \bar{O})\right) \Big/ \left(\sqrt{\sum_{i=1}^{N} (M_i - \bar{M})^2 \times \sum_{i=1}^{N} (O_i - \bar{O})^2}\right)$, -1 to 1

Is the meteorology used by models the same? (1)

2 m temperature (T2M) and 10 m wind speed (U10)





- all models underestimate the temperature and overestimate the wind speed;
- temperature underestimation is below 1% while wind speed overestimation is up to 22 %;
- the values of NMB vary more with the season than with the model;

these discrepancies are due to the different interpolation methods used to regrid the 3-D and 2-D ECMWF variables to the final CTM grid;

CMAQ behaves different from the other models since the meteorological dataset used as input was different.

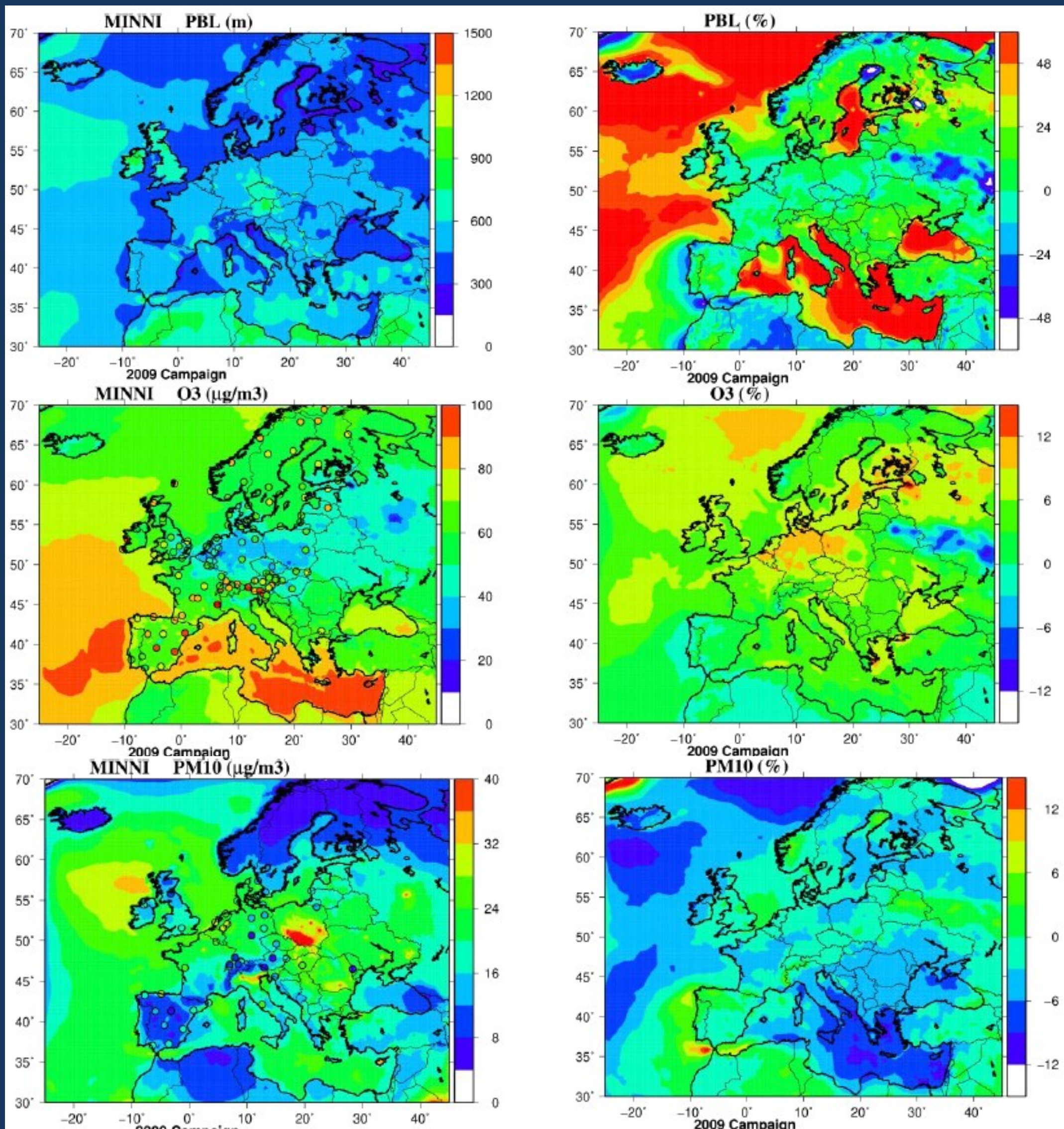
Is the meteorology used by models the same? (2)

Planetary Boundary Layer (PBL) and Rain

- all models underestimate the PBL height (up to 25%); the highest underestimation is observed for MINNI;
- all models overestimate Rain except CMAQ, which underestimate it: this may be explained due to different meteorological dataset used as input
- the values of NMB vary more with the season than with the model;

these discrepancies are due to the different interpolation methods used to regrid the 3-D and 2-D ECMWF variables to the final CTM grid but also due to different parametrizations.
(Bessagnet et al., 2014, 2016)

How much PBL height impacts on O_3 and PM10?

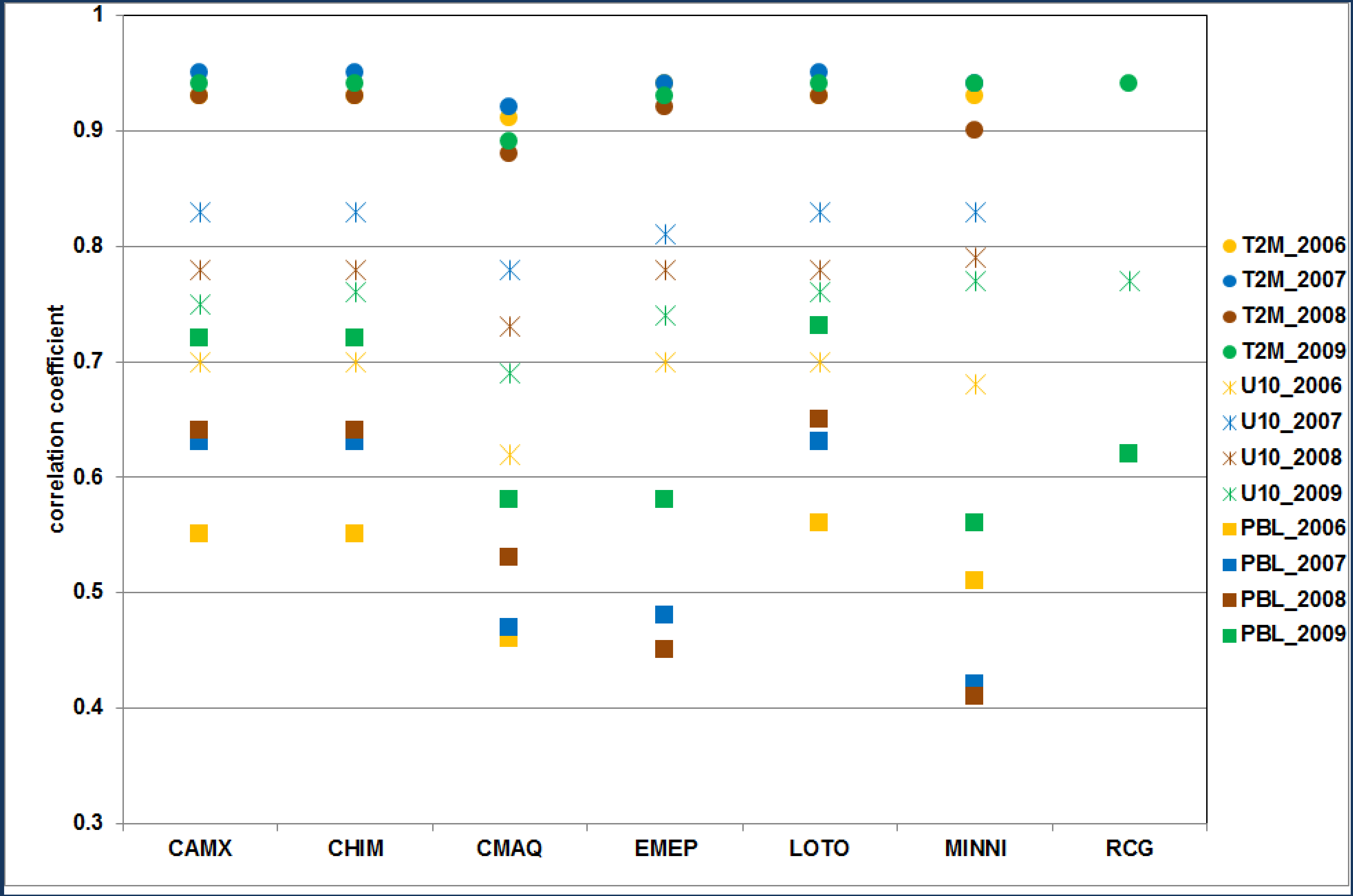


- PM10 concentrations are decreased by less than 0.5 μgm^{-3} and O_3 is increased by 2.75 μgm^{-3}.
- The variations in concentrations over the land are below 10 %.

Left graphs show the average PBL heights and the average concentrations for O3, NO2 and PM10 using MINNI's parameterizations. Right graphs show the percentage difference between the average concentrations calculated with PBL heights given by IFS (PBL_IFS) and by MINNI's parameterizations (PBL_MINNI) (Fig. 6.16, Bessagnet et al., 2014)

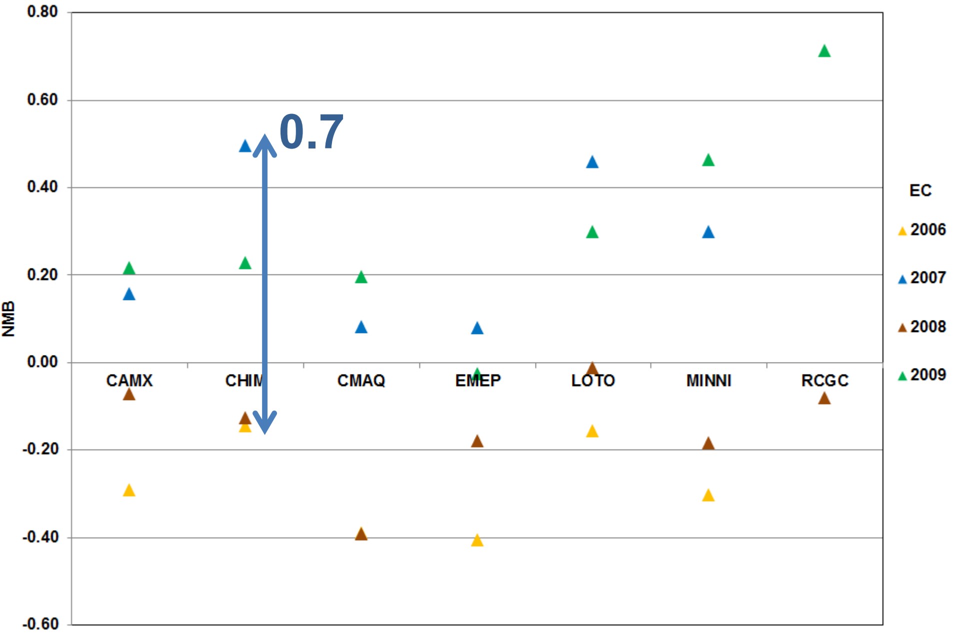
Is the meteorology used by models the same? (3)

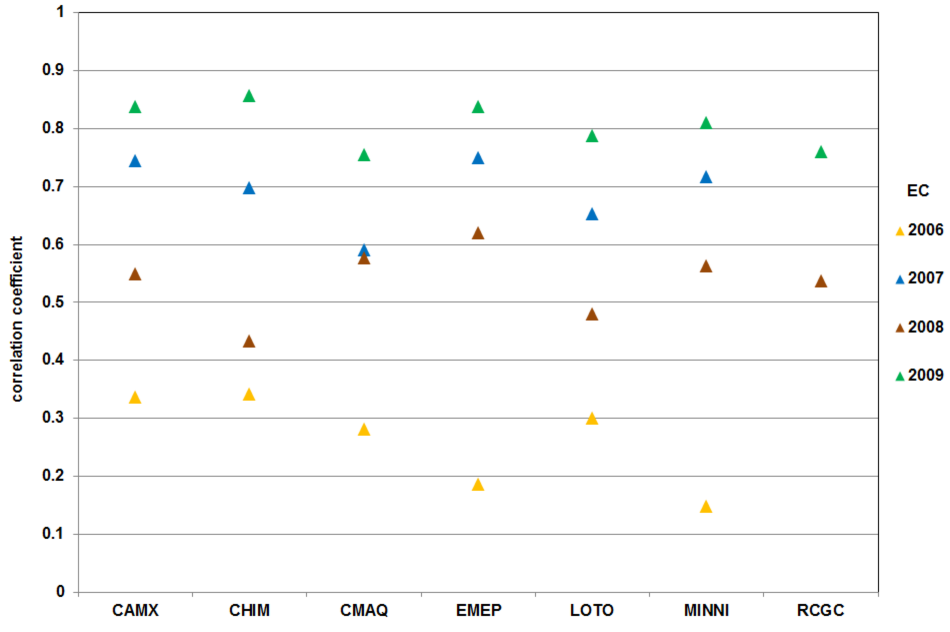
Correlations for 2 m temperature ,10 m wind speed and planetary boundary layer



T2M: all models except CMAQ have correlation above 0.9;
U10: correlations from 0.6 to 0.85, the lowest values for 2006 (summer) and the highest for 2007 (winter);
PBL: correlations from 0.4 to 0.0.7, the highest values for 2009 (spring)

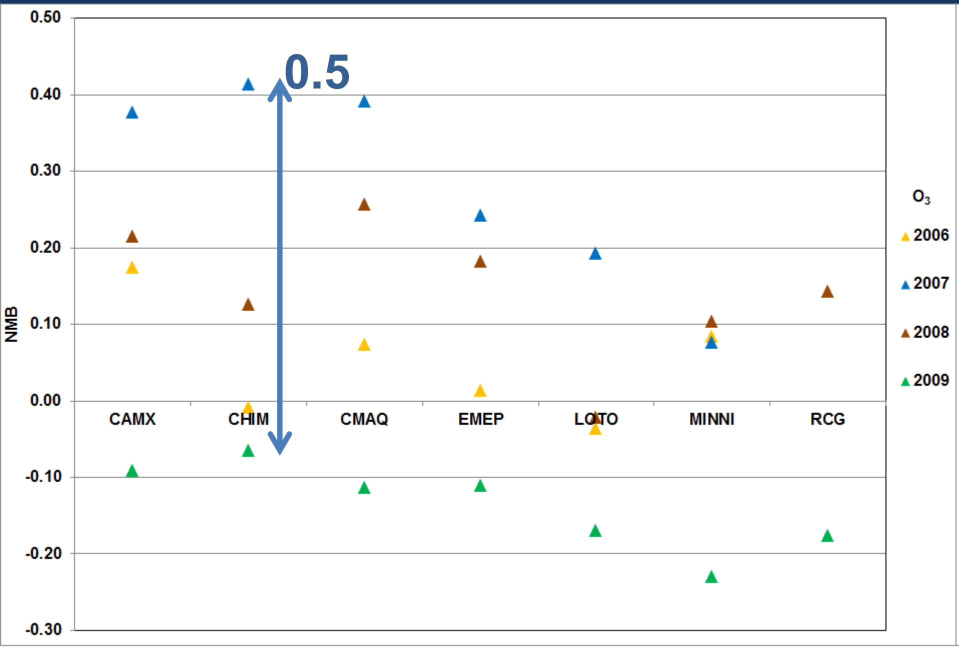
Variability of model performances for elemental carbon (EC) concentrations

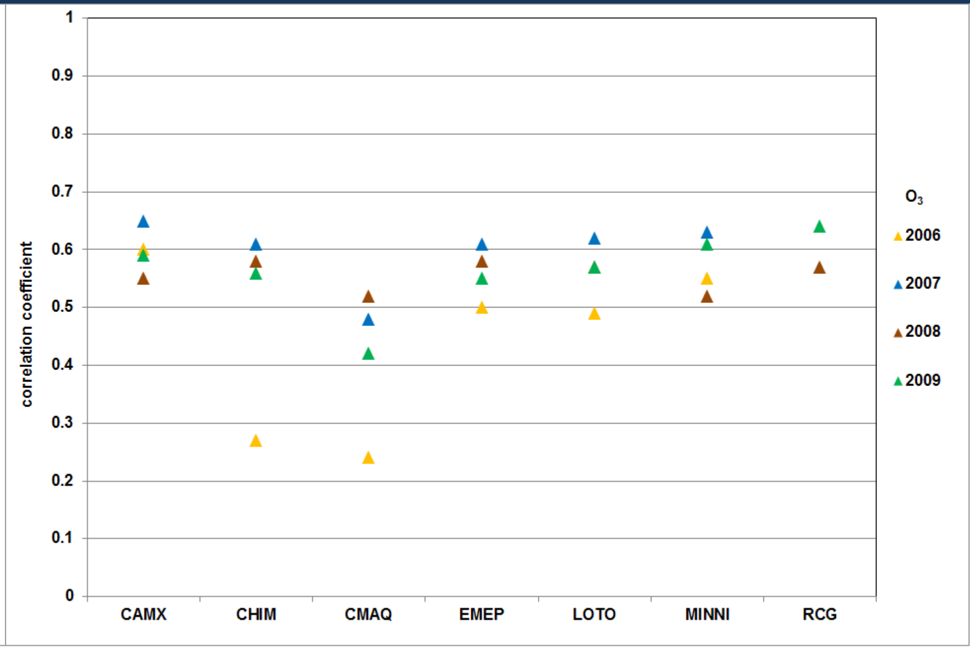




- the models underestimate and overestimate EC concentrations: NMB varies from -0.4 to 0.75;
- EC is underestimated for warm seasons (2006 – summer & 2008 – autumn) and overestimated for cold seasons (2007 –winter & 2009 – spring);
- all models show the highest correlations for 2009 (0.75-0.85) and the lowest correlations for 2006 (0.15-0.35);
- CMAQ model has similar results with the other models: the meteorological dataset impacts less than emissions;
- the values of NMB vary more with the season than with the model

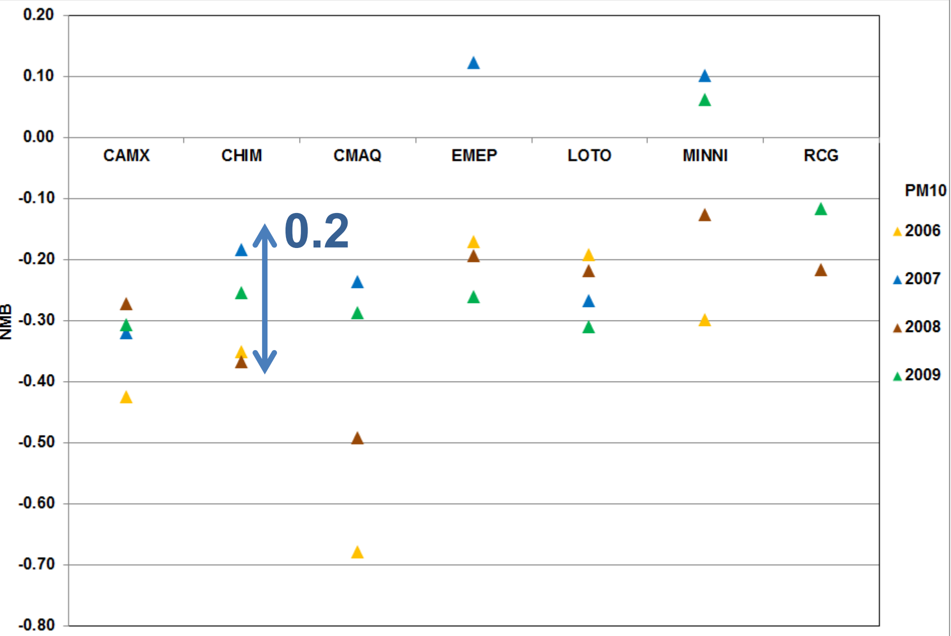
Variability of model performances for ozone (O_3) concentrations

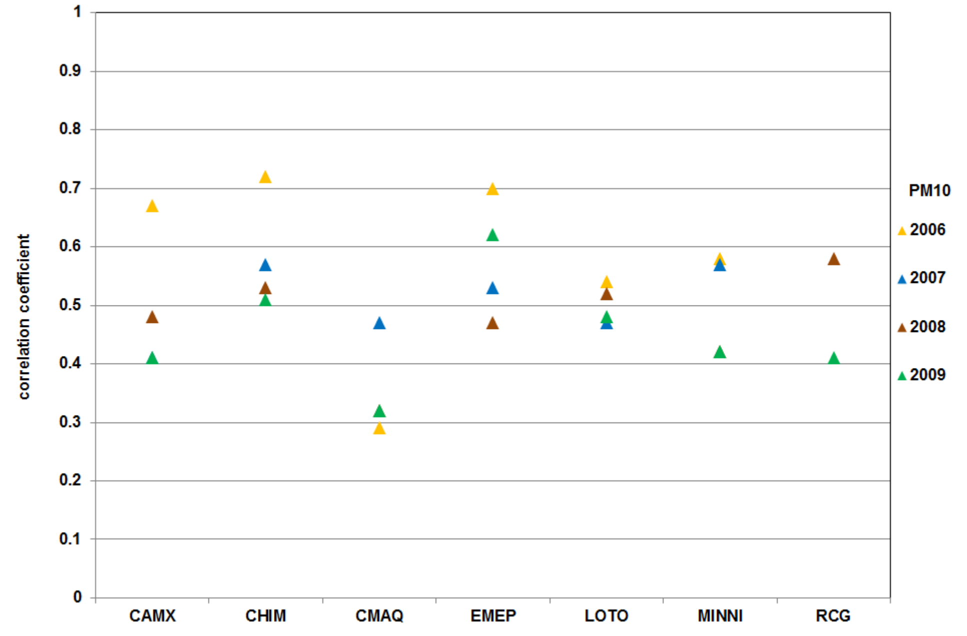




- the models underestimate O_3 concentrations in spring (2009) and overestimate them in the other seasons; the highest overestimations is observed for winter (2007)
- the correlations vary from 0.5 to 0.65 except for CMAQ, which shows lower correlations probably due to the fact that use an other meteorological dataset;
- the values of NMB vary more with the season than with the model

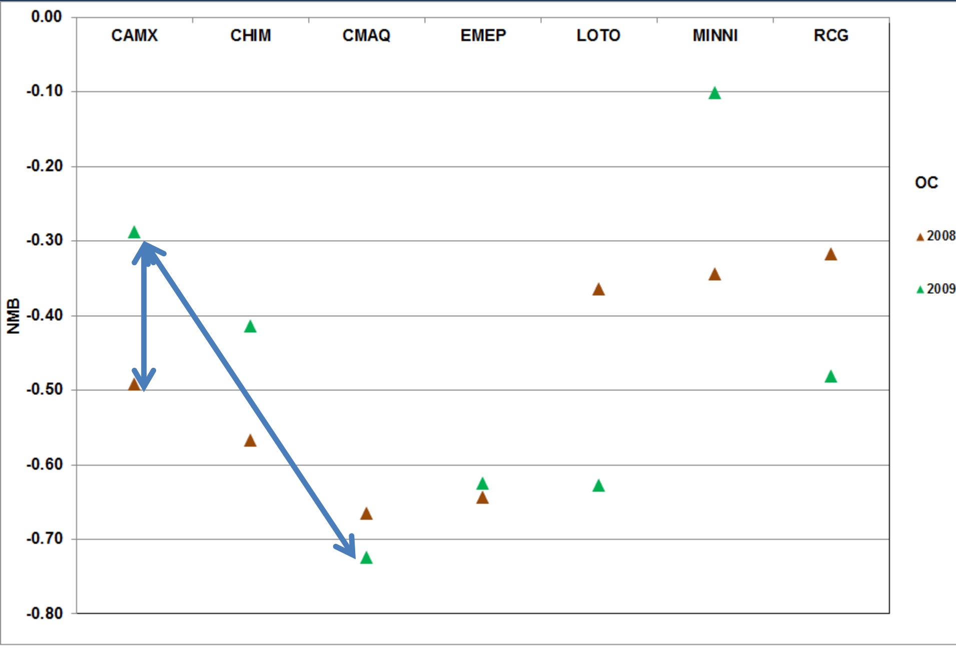
Variability of model performances for PM10 concentrations

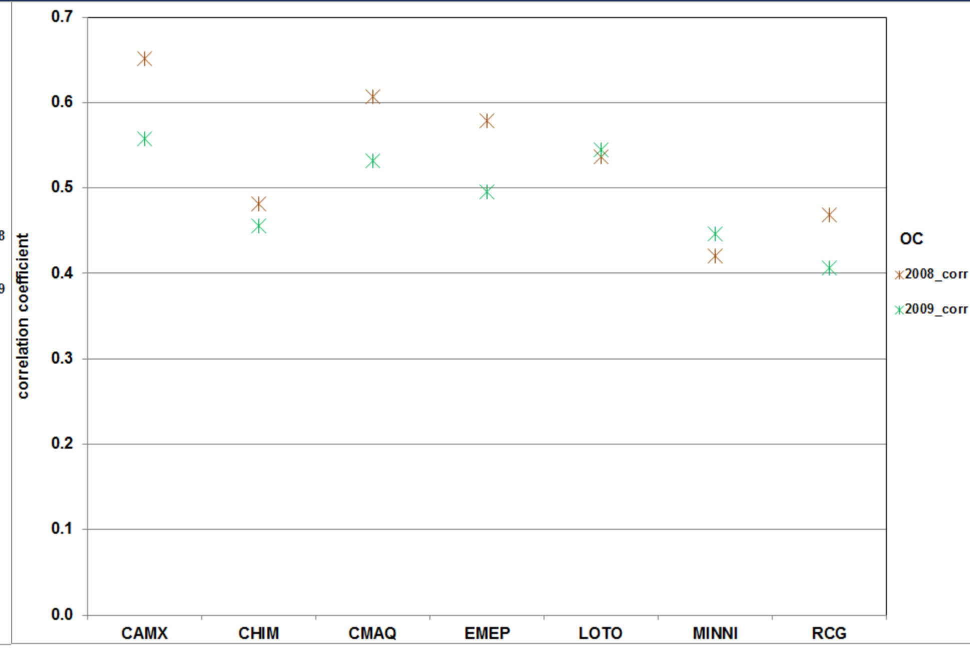




- generally, the models underestimate PM10 concentrations in all seasons; CMAQ shows the highest variability (from -0.70 to -0.20)
- the correlations vary from 0.4 to 0.7; CMAQ shows lower correlations probably due to the fact that uses an other meteorological dataset;
- CMAQ, EMEP and MINNI shows high variability with season;
- the variability between the models' NMBs is comparable with the NMBs variability with the season for a given model;

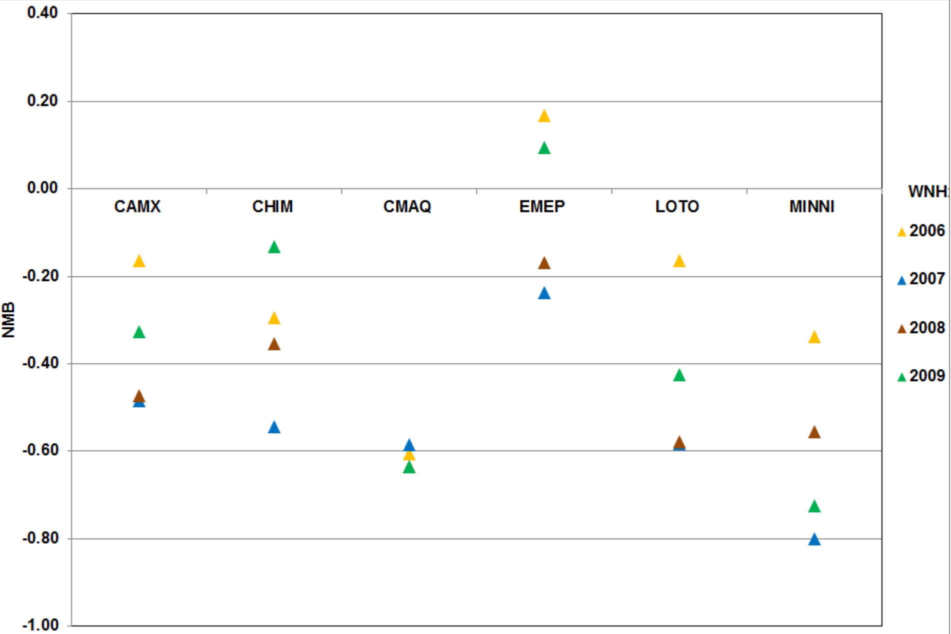
Variability of model performances for organic carbon (OC) concentrations

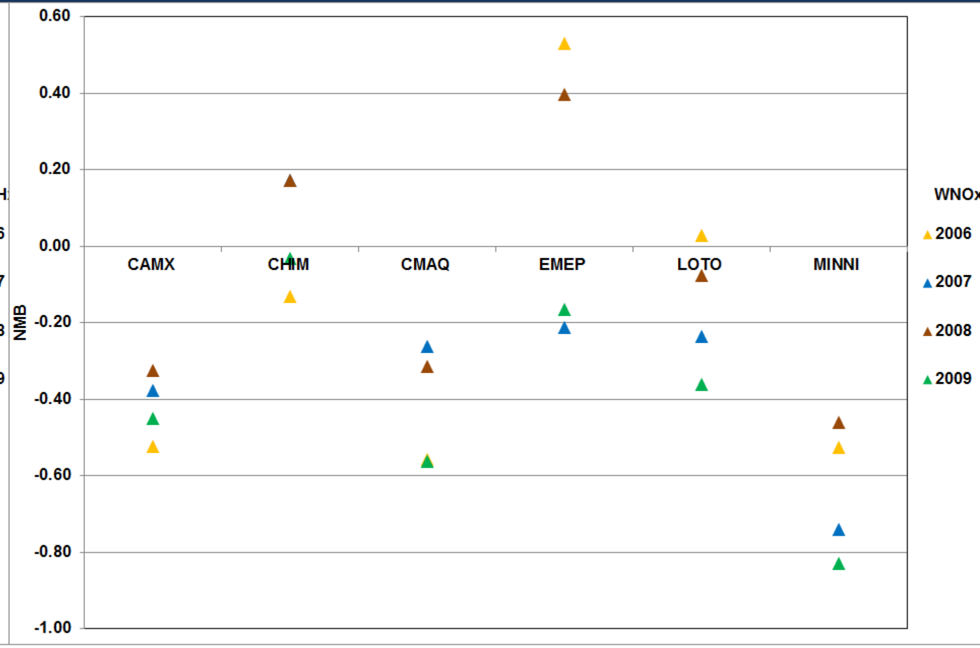




- all models underestimate OC concentrations in all seasons; CMAQ shows the highest underestimation;
- the correlations vary from 0.4 to 0.7, similar to those of PM10;
- the variability between the models' NMBs is higher than the NMBs variability with the season for a given model;

Variability of model performances for wet deposition of reduced (WNHx) and oxidised (WNOx) nitrogen species





- CMAQ shows underestimation of WNHx and WNOx coherently to underestimation of rain (negative values of NMB of WNOx & WNHx and rain
- The rest of models, apart EMEP, show underestimations of WNHx and WNOx in all seasons in spite of the fact that they overestimate the rain; this may be explained by lower NOx & NHx atmospheric concentrations and/or the inadequate wet deposition schemes. According to Vivanco et al. (2017), the underestimation of the gas scavenging efficiency may play the key role in obtaining low wet deposition loads.
- the variability between the models' NMBs is higher than the NMBs variability with the season for a given model;

Conclusion and Remarks (1)

Overall, the analysis of model outputs showed high sensitivity of models' responses with season but also with pollutant and model formulation.

- EC shows marked differences between cold and warm seasons: problems with emission inventory or its spatial/temporal distributions?

- O_3 shows different behaviour in spring with respect to the other seasons; it also shows the highest overestimations in winter: problems with precursors emissions or formulation of photochemical chemistry models?

- PM10 shows lower variability in NMBs values with season than EC and O_3 for a given model – for example, for CHIMERE, the distance between the lowest and the highest NMB is ca. 0.2 for PM10, 0.5 for O_3 and 0.7 for EC;
- PM10 behaviour with season is model dependent: some models have the highest NMB in 2006, others in 2007, etc.;
- OC is underestimated by all models in all seasons, the underestimations and the correlations are similar with those of PM10;
- OC shows higher variability of NMBs with model formulation than with the season for a given model;

Problems with emission inventory or its spatial/temporal distributions, meteorology, model formulation (chemistry and physics)?

Conclusion and Remarks (2)

- wet deposition of reduced (WNHx) and oxidised (WNOx) nitrogen are generally underestimated; problems with low NOx & NHx atmospheric concentrations and/or the inadequate wet deposition schemes, in particular underestimation of the gas scavenging efficiency in models' formulation?
- the variability between the models' NMBs is higher than the NMBs variability with the season for a given model (as for OC);

- the models do not use the same meteorology yet;
- the uncertainties of meteorological data (wind speed, PBL height and rain) may be responsible for a part of CTMs uncertainties;
- emissions inventories as total amount released in atmosphere for species relevant for air pollution and their spatial/temporal distribution require improvements;
- differences in models' formulation responsible for failures/differences are still to be identified.

Therefore, improving air quality modelling has to continue in the framework of *EURODELTA IV* and the outcomes to be presented to *HARMO19, HARMO 20, etc.*

More about EURODELTA III exercise – Part A in:

Bessagnet et al., 2014. The EURODELTA III exercise: Model evaluation with observations issued from the 2009 EMEP intensive period and standard measurements in Feb/Mar 2009" Technical Report 1/2014. http://emep.int/publ/reports/2014/MSCW_technical_1_2014.pdf

Bessagnet et al., 2016. Presentation of the EURODELTA III intercomparison exercise – evaluation of the chemistry transport models' performance on criteria pollutants and joint analysis with meteorology, Atmos. Chem. Phys., 16, 12667–12701, doi:10.5194/acp-16-12667-2016.

Vivanco et al., 2017, Joint analysis of deposition fluxes and atmospheric concentrations of inorganic nitrogen and sulphur compounds predicted by six chemistry transport models in the frame of the EURODELTAIII project, Atmospheric Environment 151, 152-175.

Mircea et al., manuscript in preparation "The EURODELTA III exercise: evaluation of air quality models' capacity to reproduce the carbonaceous aerosol".

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