ScaleDep

Performance of European chemistry-transport models as function of horizontal spatial resolution

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- Objective of the ScaleDep exercise
- Methodology
- Input data
- Modelling teams
- Results: PM10, NO_2, O_3
- Conclusions
- Final remarks

Objective of ScaleDep

The EMEP MSC-W models have been instrumental to the development of AQ policies in Europe since the late 1970s.
In the 1990s the EMEP models became also the reference tools for atmospheric dispersion calculations as input to the IAM, which supports the development of AQ polices in the EU.

Since 1999, the EMEP model has been run on a 50x50 km^2 resolution.
However, the last years, modification of the EMEP grid has been discussed, an important aspect of which is the grid resolution.
An increase in model resolution requires that the input data (most importantly the emissions) are available on the same scale.

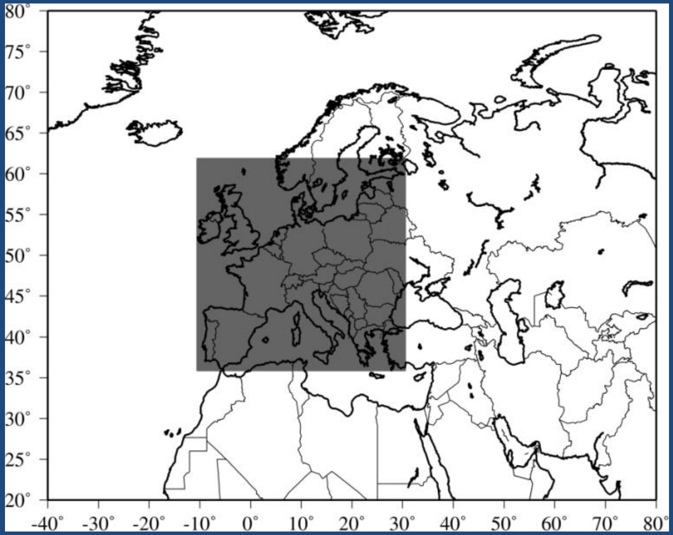
As an increase in model resolution will increase the computational costs cubically, it is important to determine the "optimum resolution", at which scale the increase in resolution does not give improvement in performance any longer and for which the computational effort is not too large.

Objective of ScaleDep

To support EMEP in this decision,
an initiative was taken for a model inter-comparison exercise aimed at analysing the model performance of different chemical-transport models as a function of model horizontal spatial resolution.

Methodology

2009



Domain	nx	ny	ΔLon (degrees)	ΔLat (degrees)	ΔLon x ΔLat (km x km)	SW corner grid centre (Lon / Lat)
EC4M1 **56 km**	41	52	1.0	0.5	56 x 56 (N) 88 x 56 (S)	-10.000 / 36.125
EC4M2 **28 km**	82	104	0.5	0.25	28 x 28 (N) 44 x 28	-10.250 / 36.000
EC4M3 **14 km**	164	208	0.25	0.125	14 x 14 (N) 22 x 14 (S)	-10.3750 / 35.9375
EC4M4 **7 km**	328	416	0.125	0.0625	7 x 7 (N) 11 x 7 (S)	-10.43750 / 35.90625

Output Files of 4.6 Gb !

Input data

European Commission

Input: All other input parameters were <u>not</u> prescribed.

Meteo:

- In case of meteorology most models use data from ECMWF.
  The ECMWF meteorology has a resolution of ca. 16km, so that models running at e.g. 7km are essentially running with fine-scale emissions but somewhat smoothed meteorology.
- RCGC used diagnostic meteorology from TRAMPER
- CMAQ used meteorological fields from the WRF-ARW model,
  It is the only model running the meteo at true 7km.

Emissions

The anthropogenic emission input was harmonized by using a common EC4MACS emission dataset. The gridded emissions were provided by INERIS, and based on a merging of databases from:

- TNO 0.125°×0.0625° emissions for 2007 from MACC
- EMEP 0.5°×0.5° for 2009

Requested output

Time freq	PM	Gases	Deposition	Meteo
Hourly	PM2.5, PM10	O_3, NO_2, NO	-	U10, T2m, Kz, PBL, u*
Daily	PM2.5, PM10 PPM_fine, PPM_coarse NO_3_f, NO_3_c SO_4_f, SO_4_c NH_4_f, NH_4_c SOA_f, SOA_c Dust_f, Dust_c SS_f, SS_c	SO_2, NH_3, HNO_3	D_NO_x, D_SO_x, D_NH_x, W_NO_x, W_SO_x, W_NH_x	Rain amount

Which means approx 55 Gb per model !

AQ Models

Five modelling teams participated in the exercise:

- **EMEP MSC-W,**
- **CHIMERE (INERIS),**
- **LOTOS-EUROS (TNO),**
- **RCGC (Berlin Freie Universität),**
- **CMAQ (Barcelona SC).**

Model details: See report

Vertical model structure:

	EMEP	CHIM	LOTOS	RCGC	CMAQ
Vertical layers	20 sigma	9 sigma	4 (3 dyn and 1 surf)	5 fixed layers	15 sigma
Vertical extent	100 hPa	500 hPa	3500 m	3000 m	50 hPa
Depth 1st layer	90 m	20 m	25 m	25 m	19 m

Monitoring Stations

European Commission

OBS data from two monitoring networks were used .

EMEP	AIRBASE
O_3	O_3
O3_8HrMax	O3_8HrMax
NO_2	NO_2
PM10	PM10
SO_4, NO_3	

U –Urban BG measurements within a radius of 30 km around each city area.
R – Rural BG measurements within a radius of 200 km.
E – EMEP measurements radius of 200 km

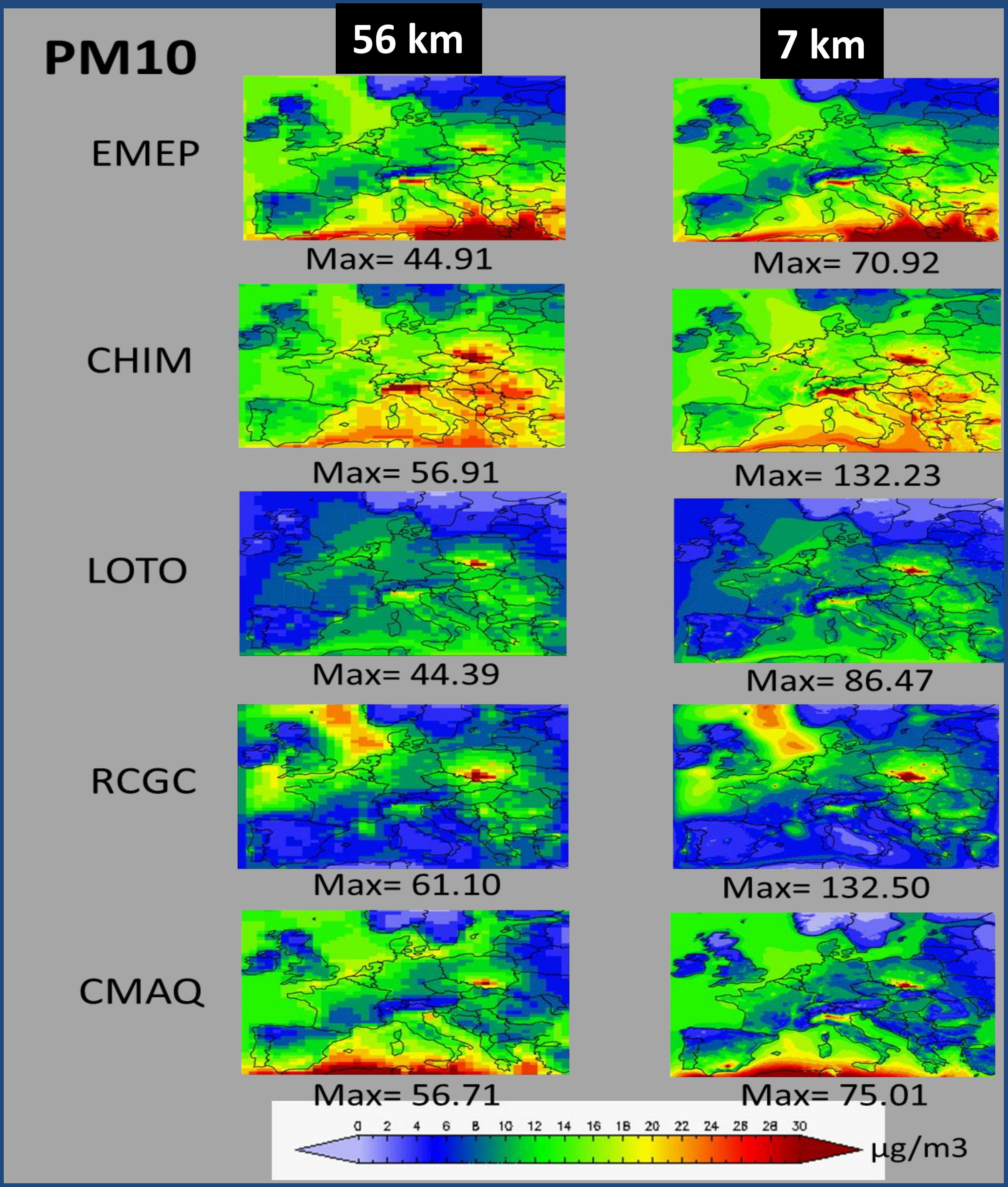
Overview of Stations

		PM10			NO2				O3	
		Urban	Rural	EMEP	Urban	Rural	EMEP	Urban	Rural	EMEP
Amsterdam	AMS	2	11		7	12		1	12	
Athens	ATH				2	1		2	1	
Barcelona	BAR	5	4		5	6		4	6	
Berlin	BER	5	10	1	6	9		3	9	
Bilbao	BIL	4	5	1	4	5	1	4	5	1
Bruxelles	BRU		11		1	16		1	16	
Bucarest	BUC	1	0			1		1	1	
Budapest	BUD	1	2	2	1	2		1	2	2
Cologne	COL		7			9			9	
Dublin	DUB	2	2		2	2		1	2	
Hambourg	HAM	6	7	1	6	10		2	10	
Krakow	KRA	5	3		3	3		2	3	
Leeds	LEE	1			2	3	2	2	3	3
Lisbon	LIS	8	4		11	4		10	4	
London	LON	3	3	1	5	5	3	5	5	3
Lyon	LYO	2	2		3	9		3	9	
Madrid	MAD	5	9	3	7	9	3	7	9	3
Marseille	MAR	4	1		4	10		1	10	
Milan	MIL	8	7		9	13		9	13	
Munich	MUN	1	5		1	10		1	10	
Naples	NAP		1			2			2	
Paris	PAR	7	6		19	11		12	11	
Prague	PRA	4	20	1	4	14		2	14	1
Rome	ROM	6	2	1	6	2		6	2	
Sevilla	SEV	2	2		5	3		4	3	
Sofia	SOF		1			1			1	
Stockholm	STO	1	2	1	1	2		1	2	1
Valencia	VAL	2	3	1	2	5	1	2	5	1
Vienna	VIE	3	21	1	4	19		3	19	
Warsaw	WAR	10			6	3		3	3	1
Total		98	151	14	126	201	10	93	201	16

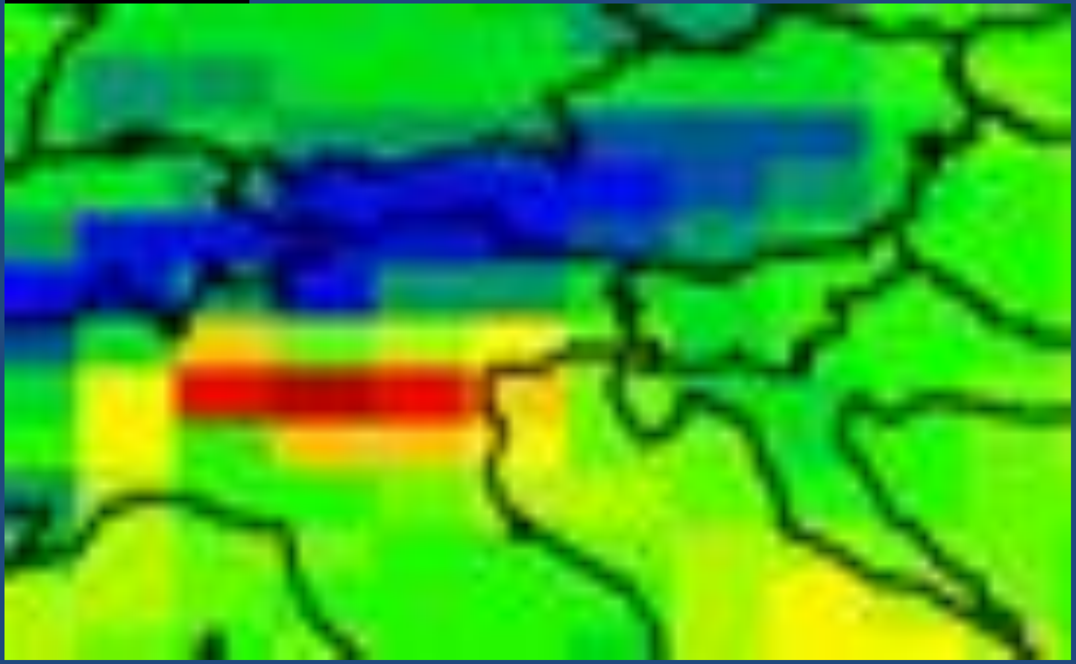
Analysis

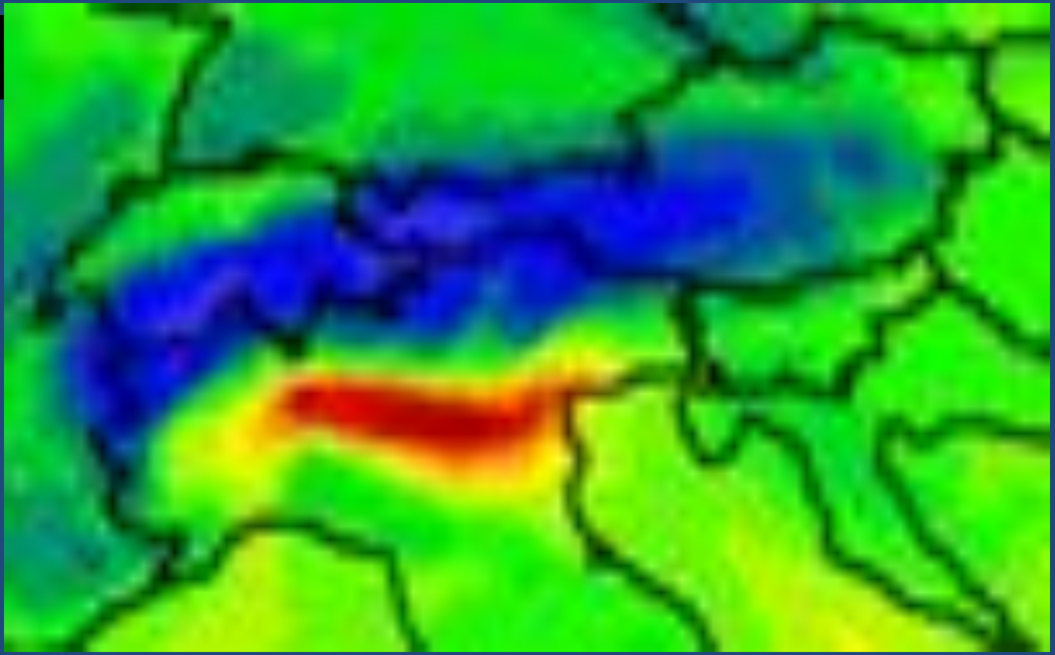
The ScaleDep analysis is performed for

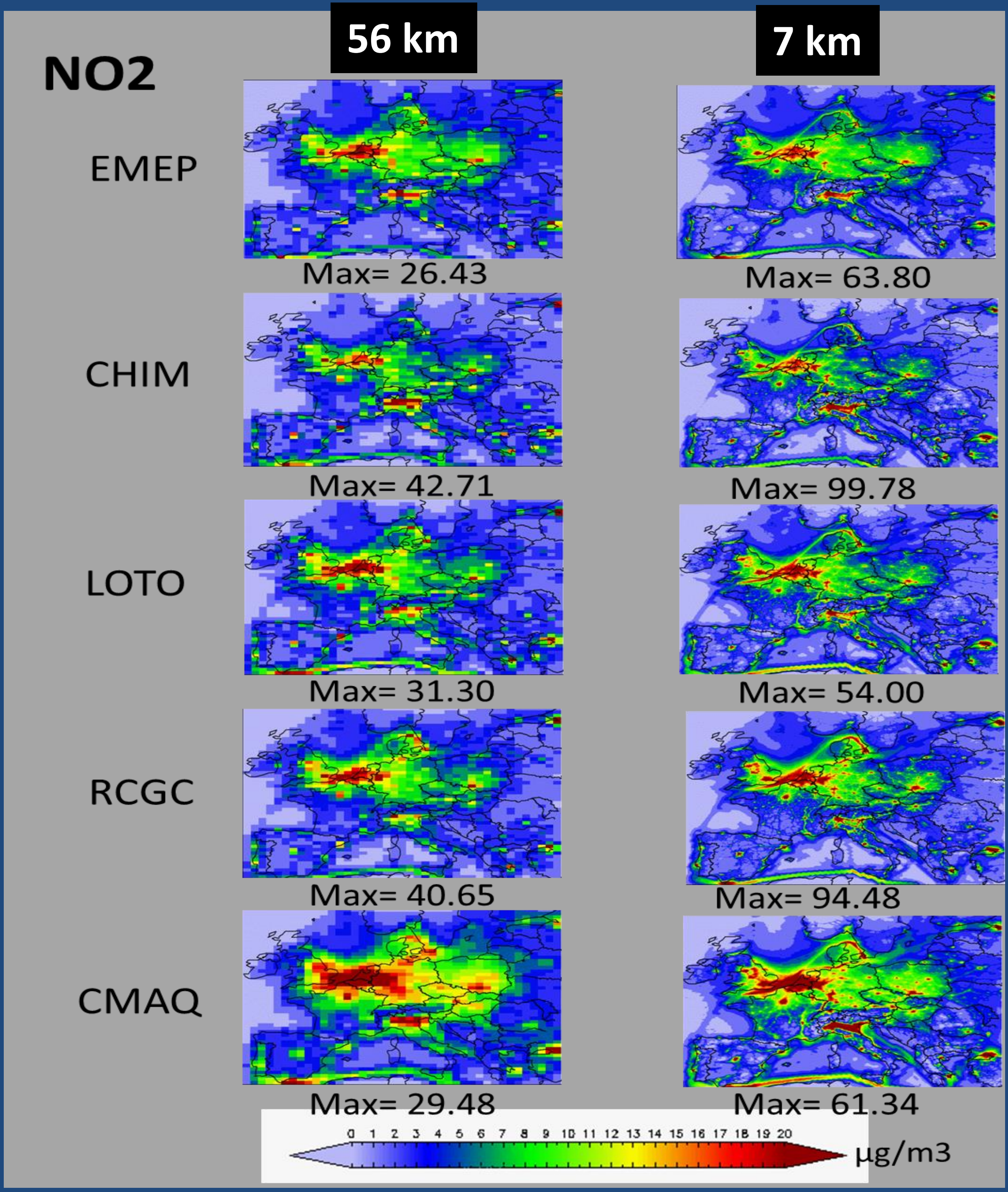
- Daily mean PM10 concentrations
- Hourly NO_2
- Daily maximum of the running 8 hourly mean O_3


PM10
56 km
7 km
EMEP
Max= 44.91
Max= 70.92
CHIM
Max= 56.91
Max= 132.23
LOTO
Max= 44.39
Max= 86.47
RCGC
Max= 61.10
Max= 132.50
CMAQ
Max= 56.71
Max= 75.01
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
µg/m3

EMEP

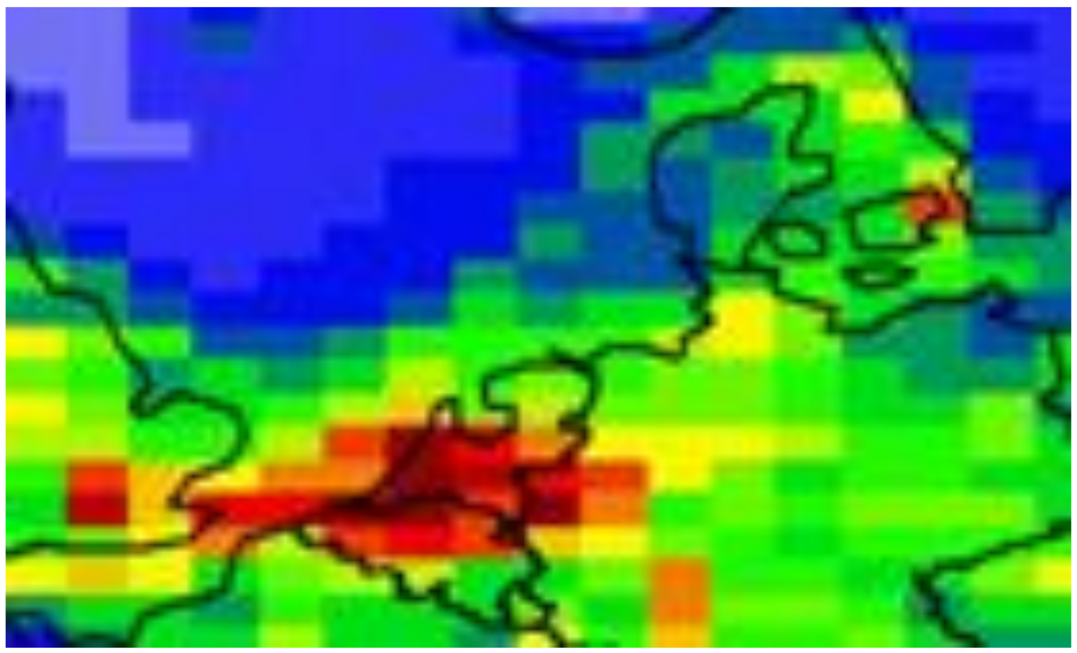




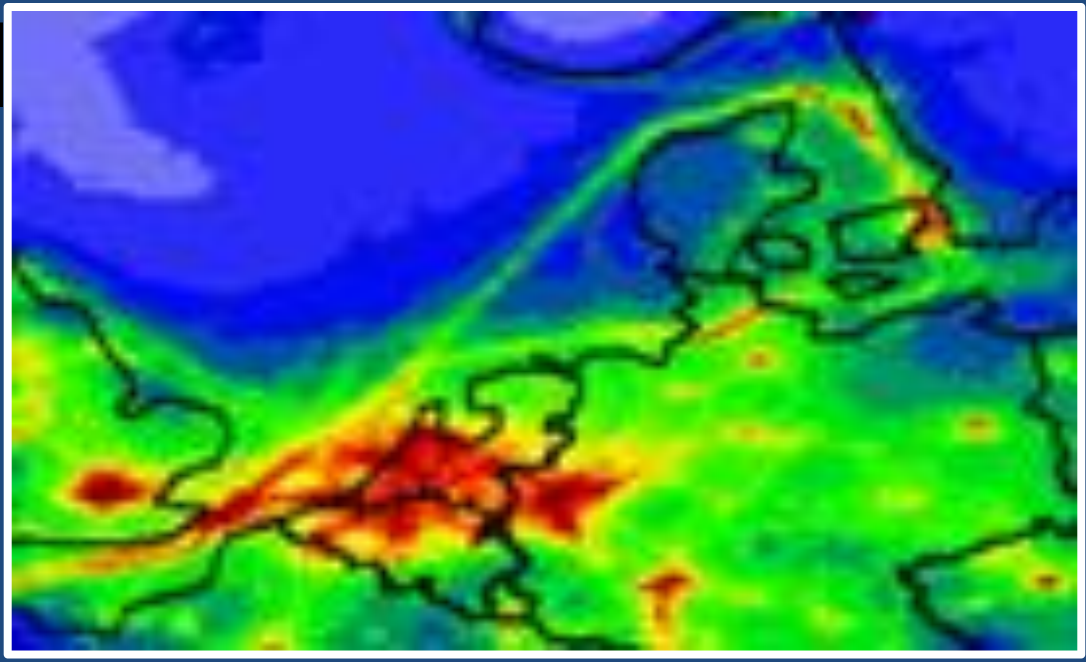

NO2
56 km
7 km
EMEP
Max= 26.43
Max= 63.80
CHIM
Max= 42.71
Max= 99.78
LOTO
Max= 31.30
Max= 54.00
RCGC
Max= 40.65
Max= 94.48
CMAQ
Max= 29.48
Max= 61.34
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
µg/m3

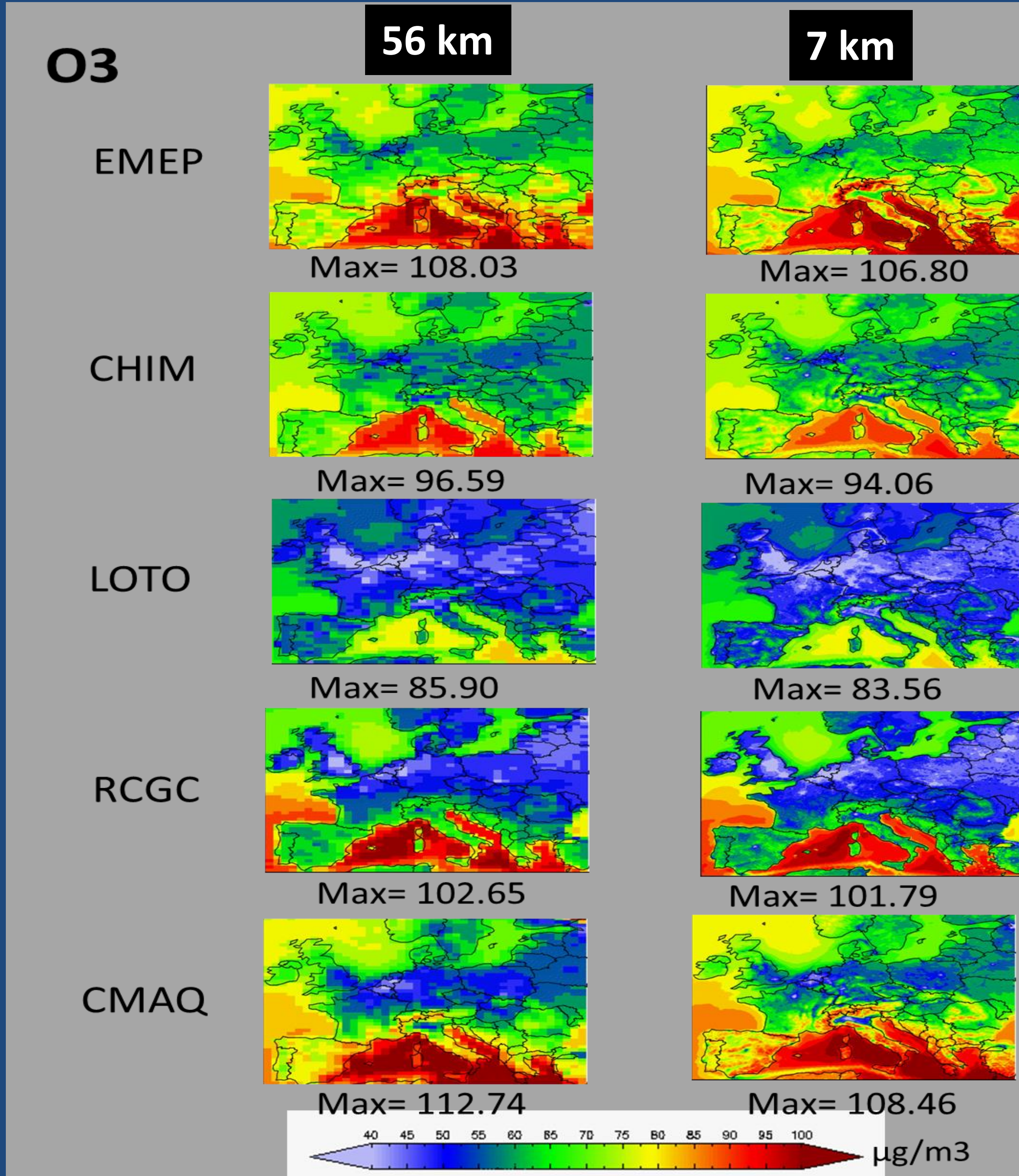
EMEP

56 km

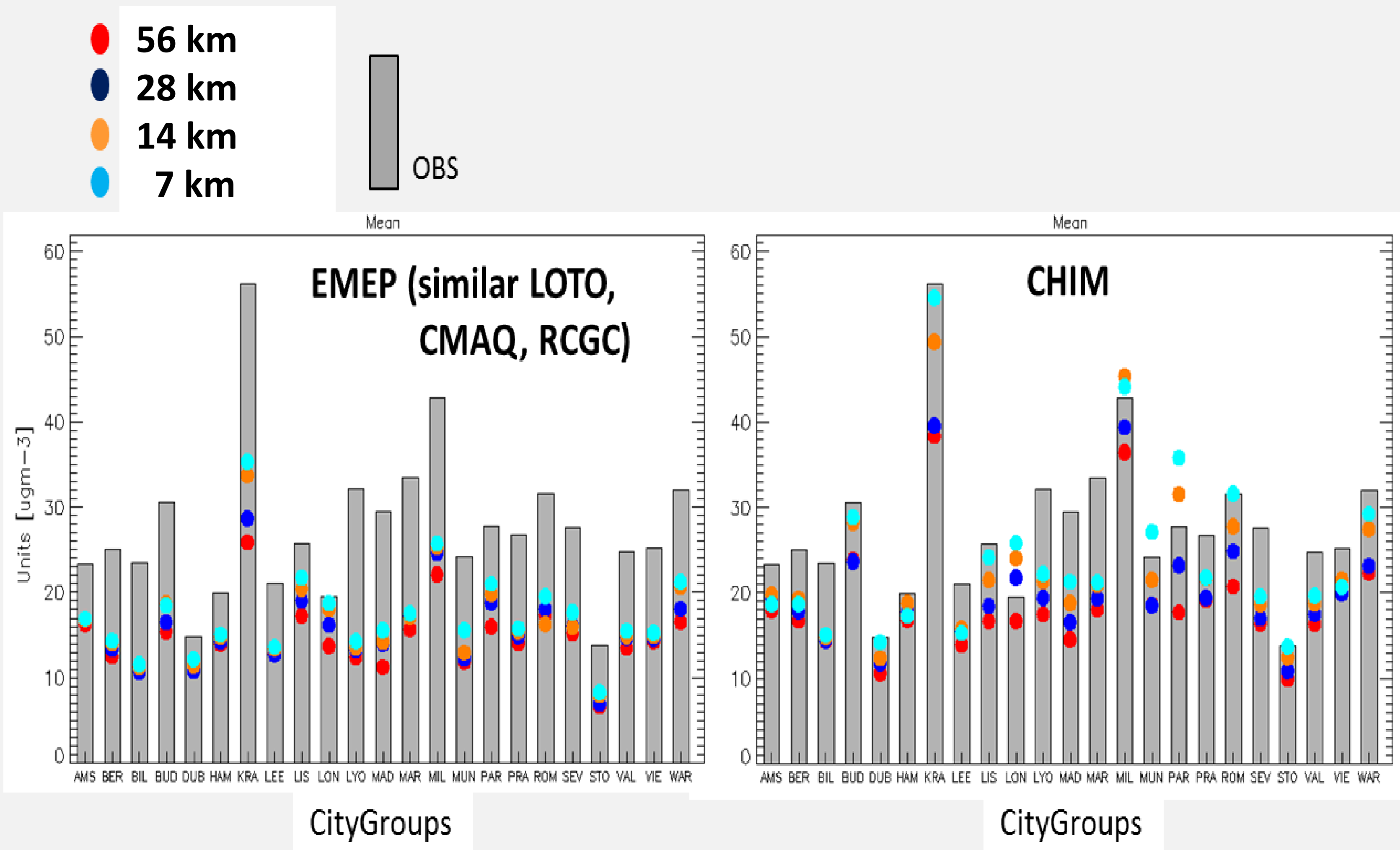


7 km



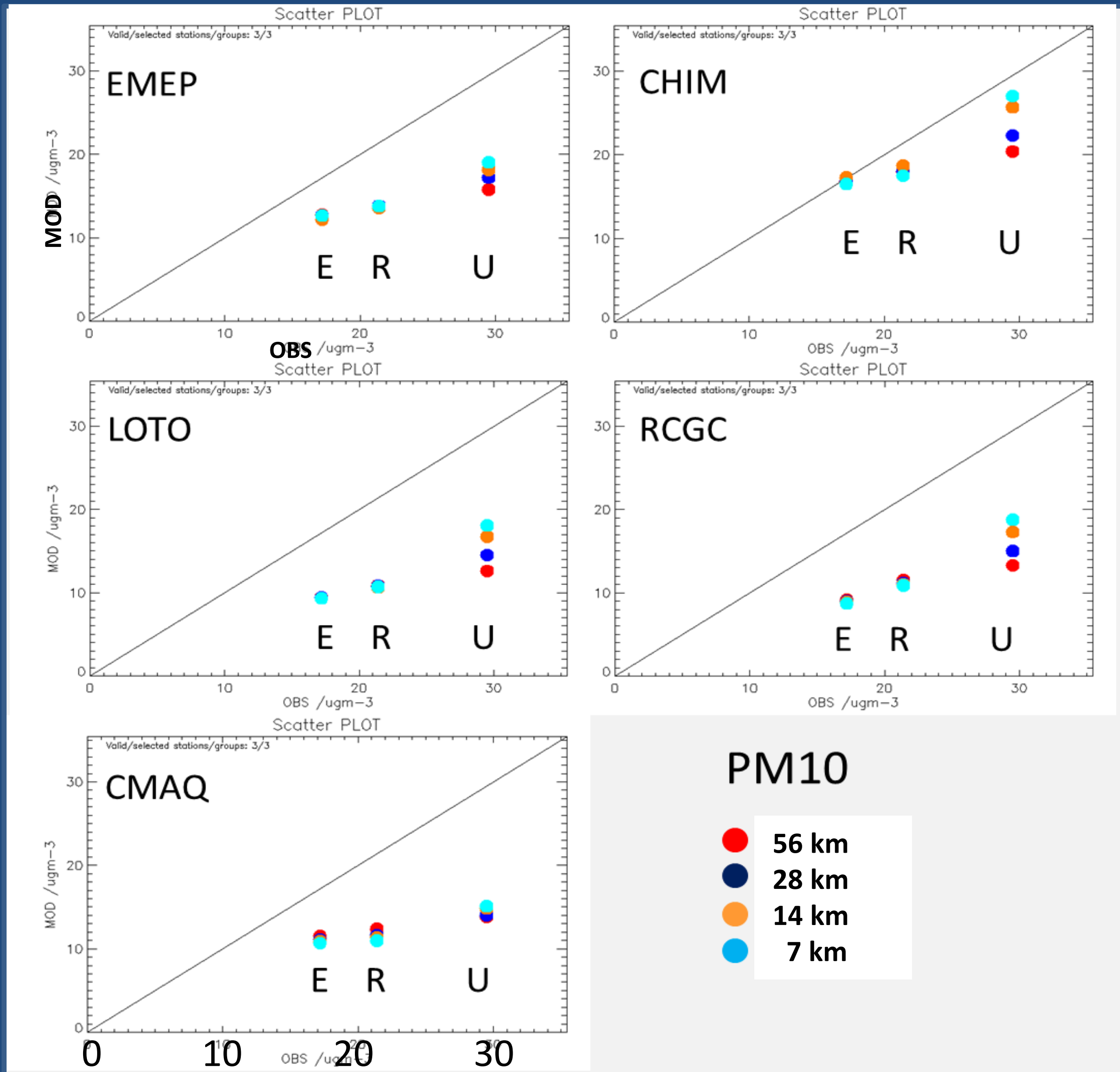

O3
56 km
7 km
EMEP
Max= 108.03
Max= 106.80
CHIM
Max= 96.59
Max= 94.06
LOTO
Max= 85.90
Max= 83.56
RCGC
Max= 102.65
Max= 101.79
CMAQ
Max= 112.74
Max= 108.46
40 45 50 55 60 65 70 75 80 85 90 95 100
µg/m3

Urban annual PM10 per City Group



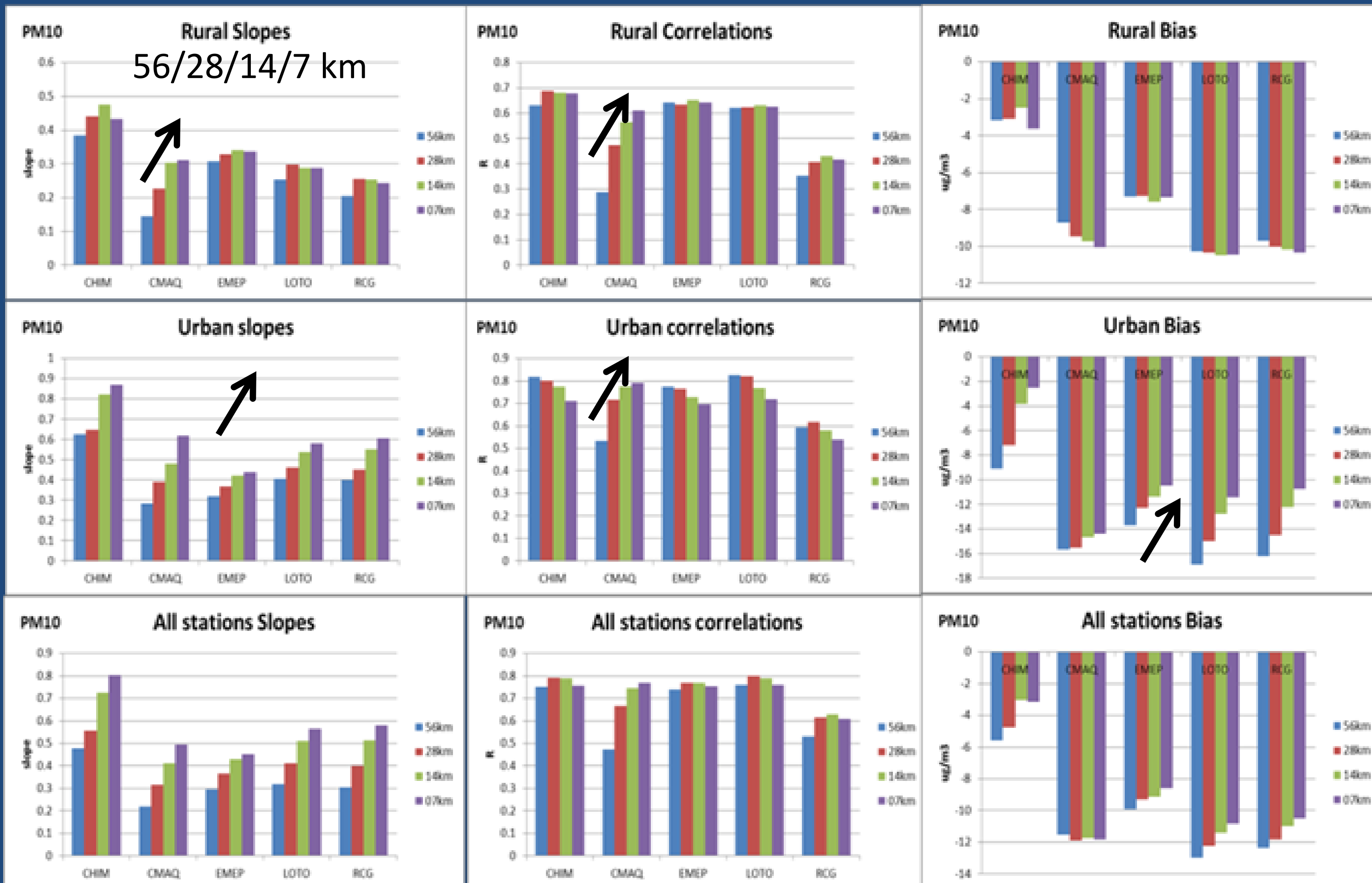
Annual PM10 EMEP/Rural/Urban

European Commission



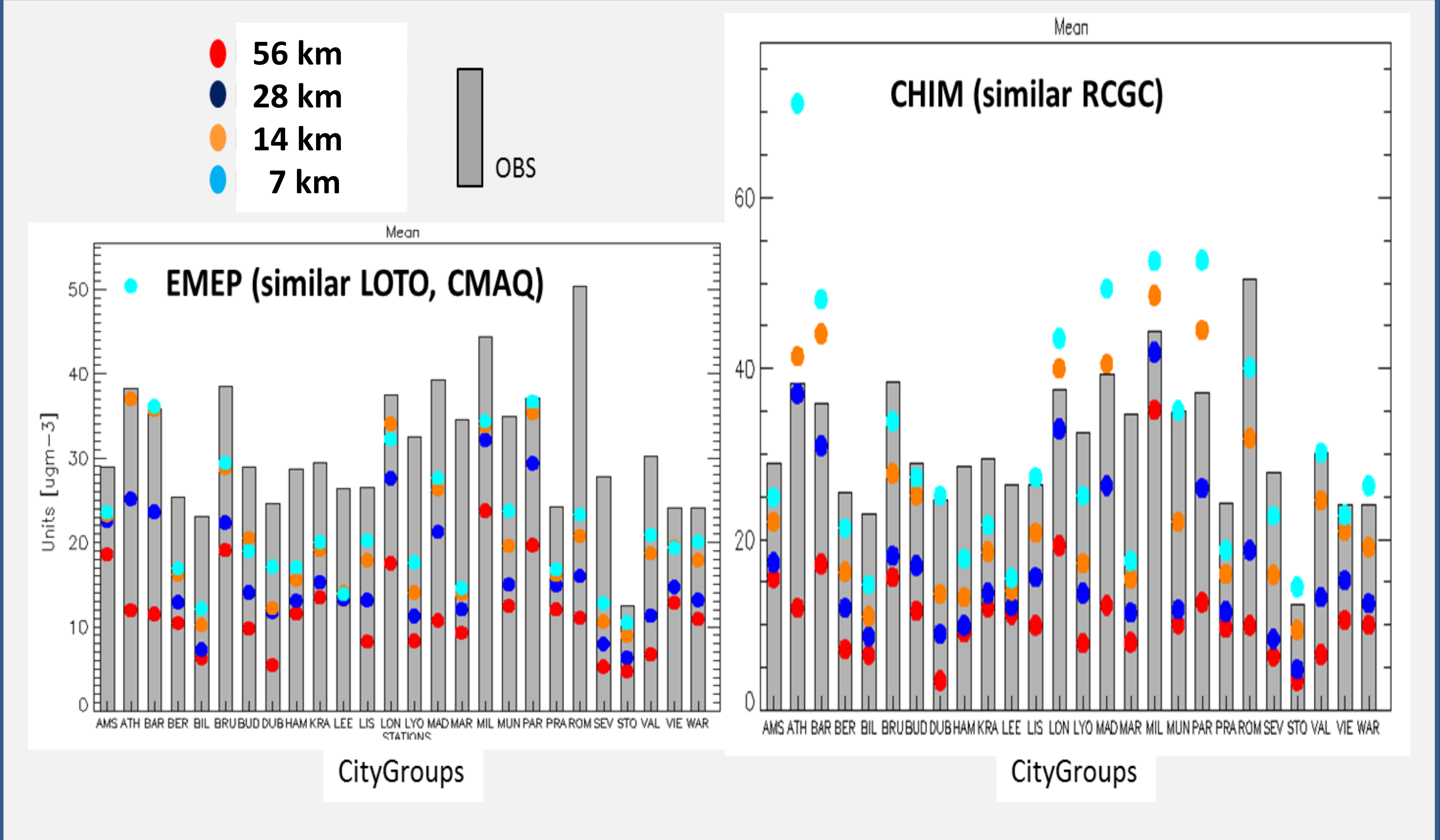
Annual PM10 Statistical Analysis

European Commission



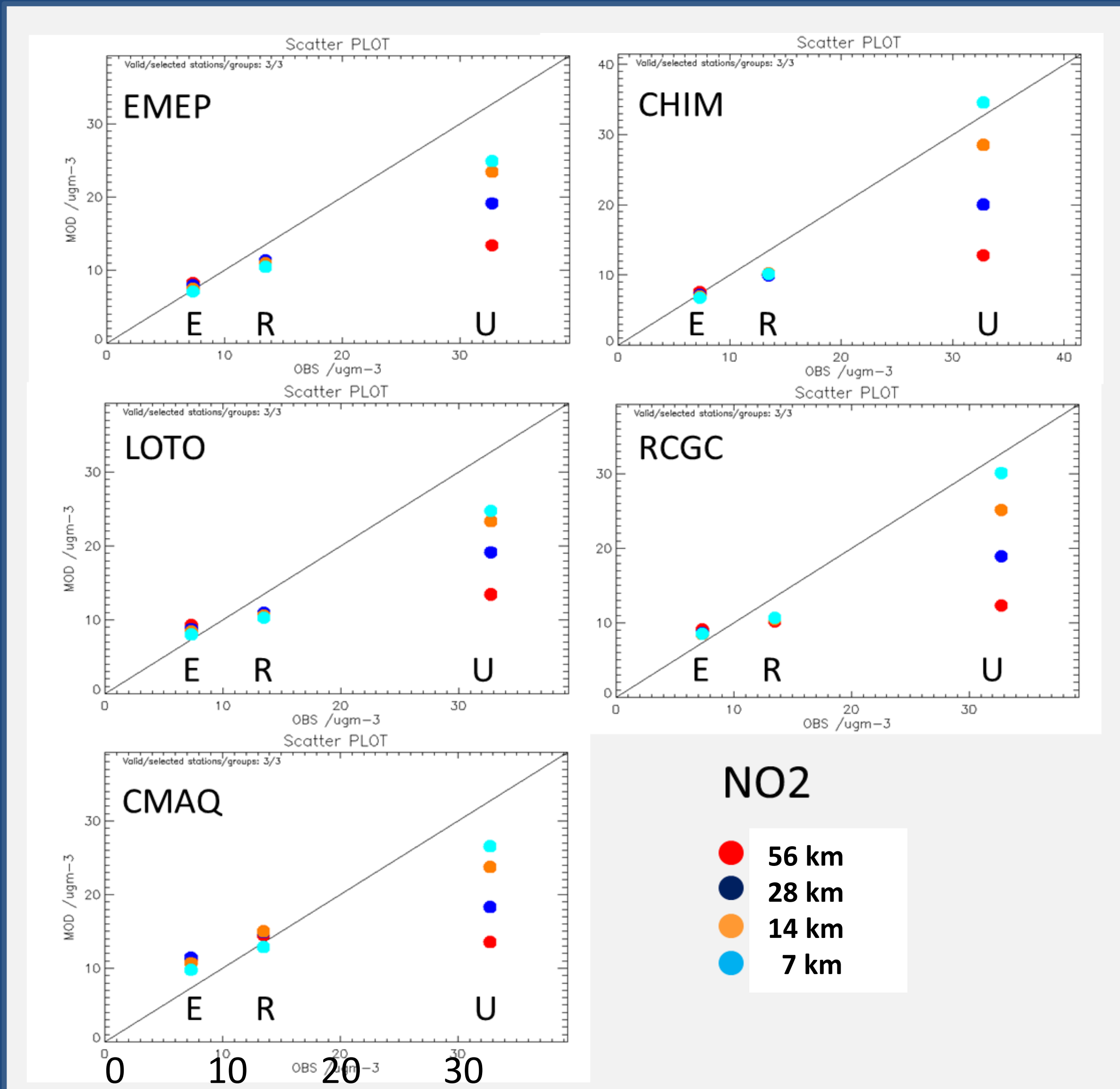
Note the different scales between the station groups

Urban annual NO_2 per City Group

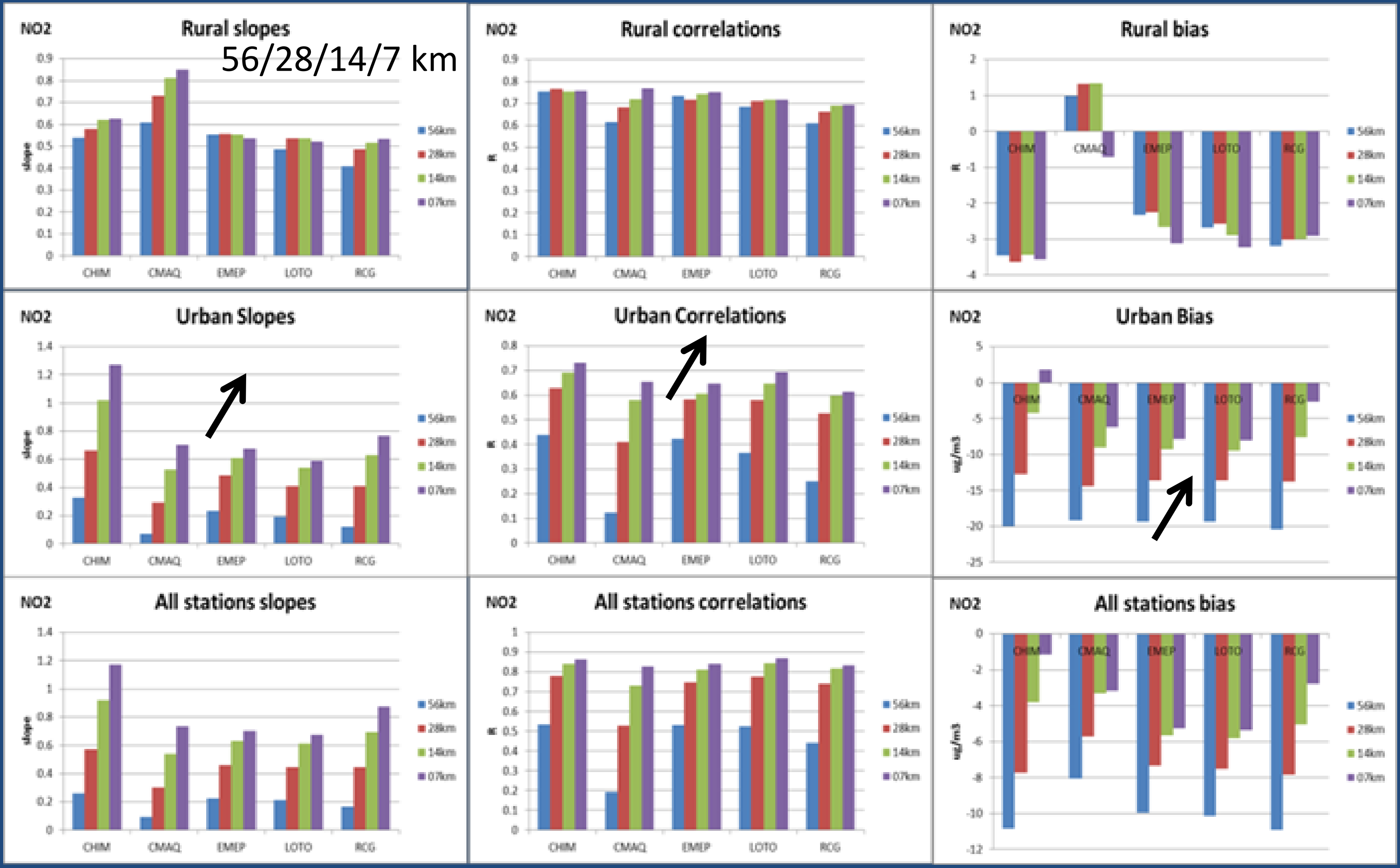


Annual NO_2 EMEP/Rural/Urban

European Commission

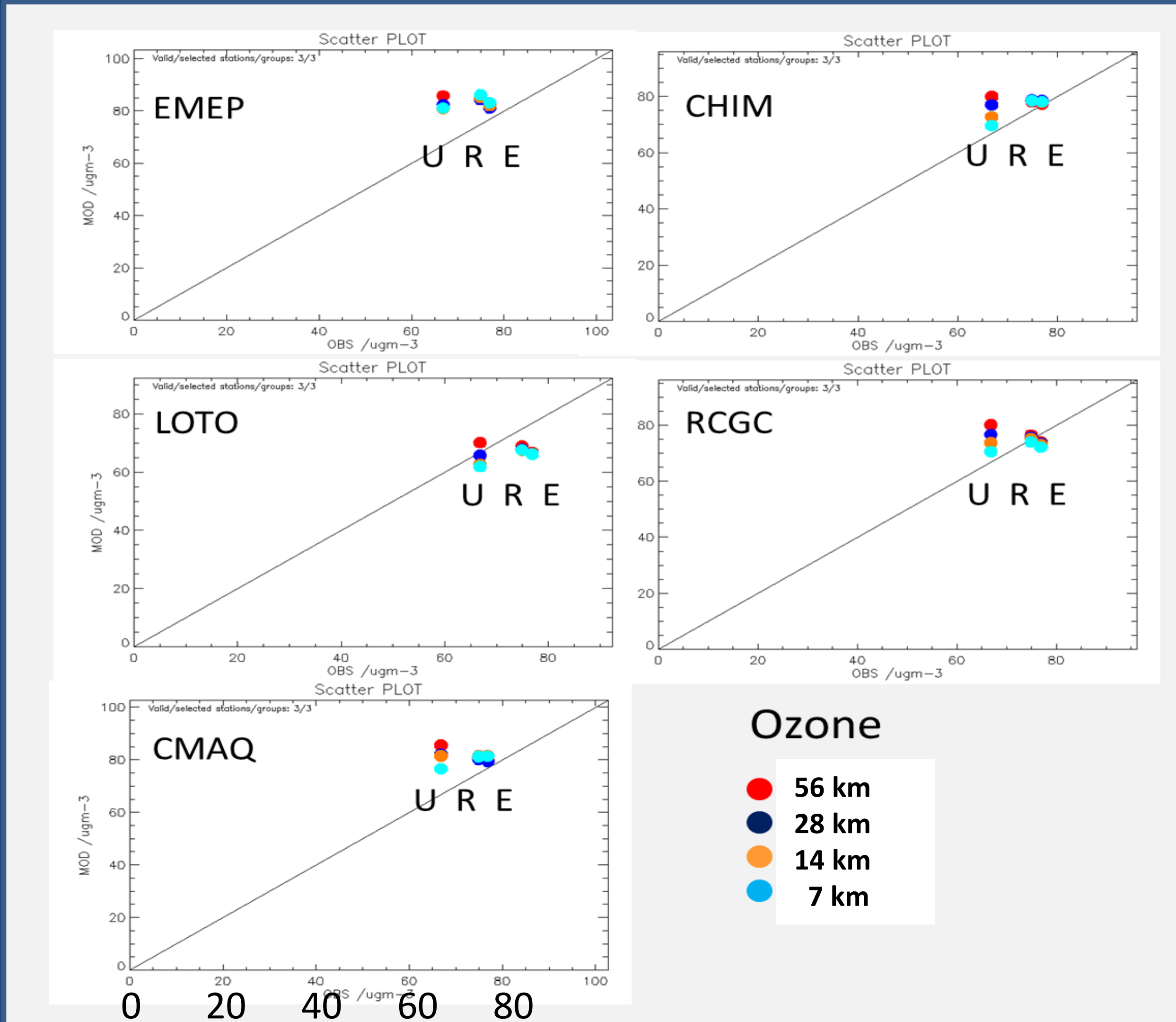


Annual NO_2 Statistical Analysis



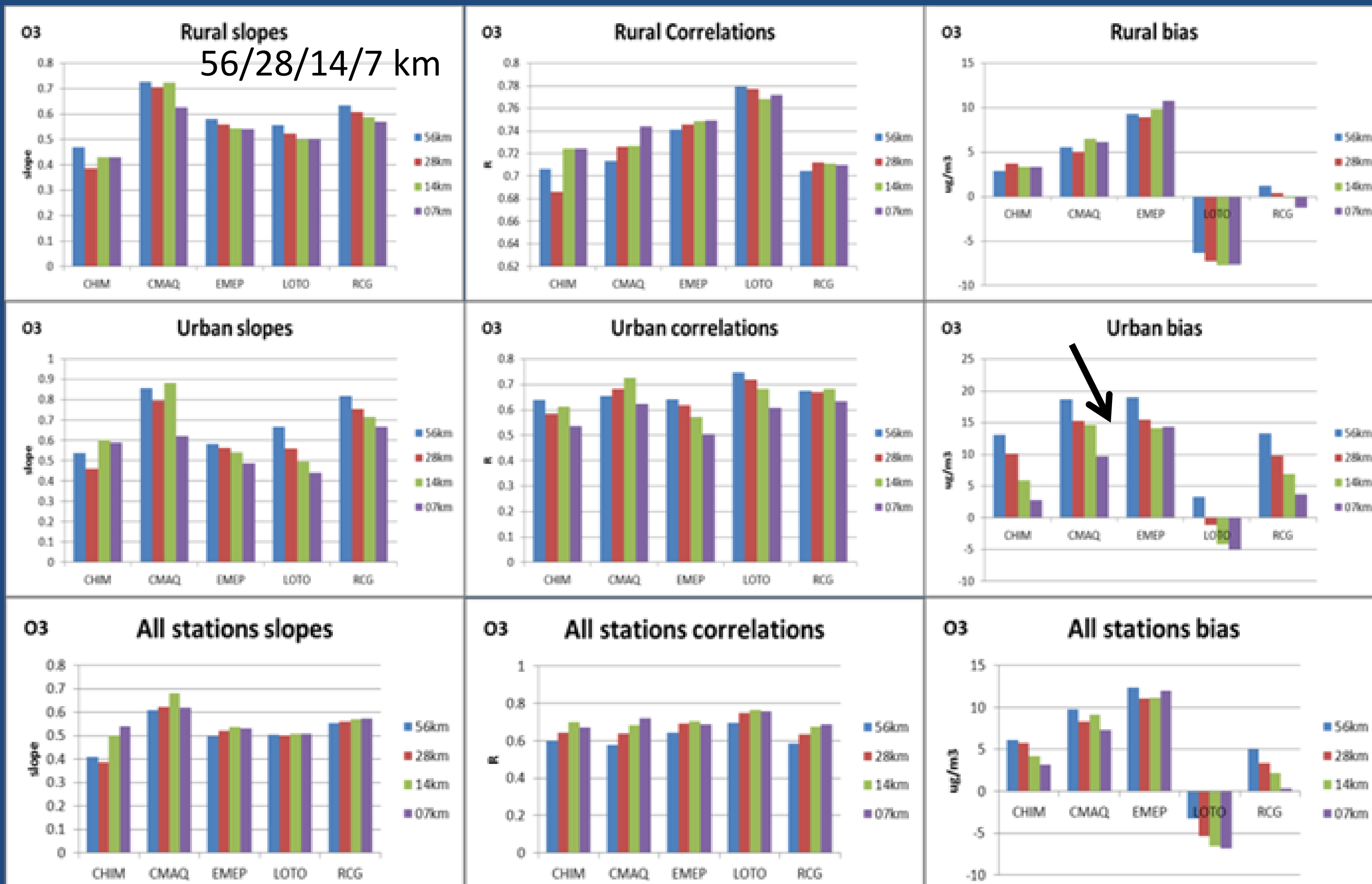
Note the different scales between the station groups

Annual O_3-8hrMax EMEP/Rural/Urban



Annual O_3-8hrMax Statistical Analysis

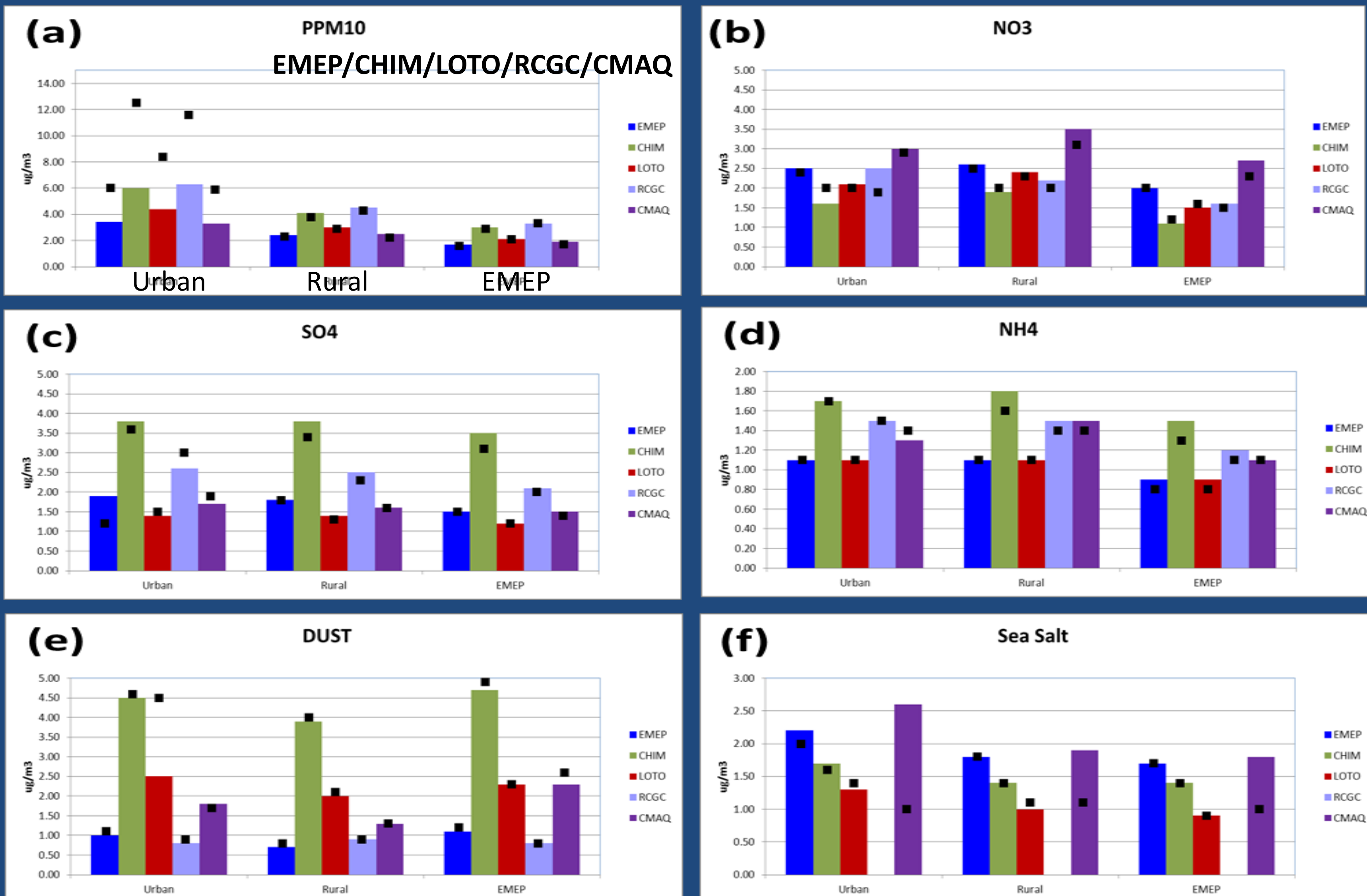
European Commission



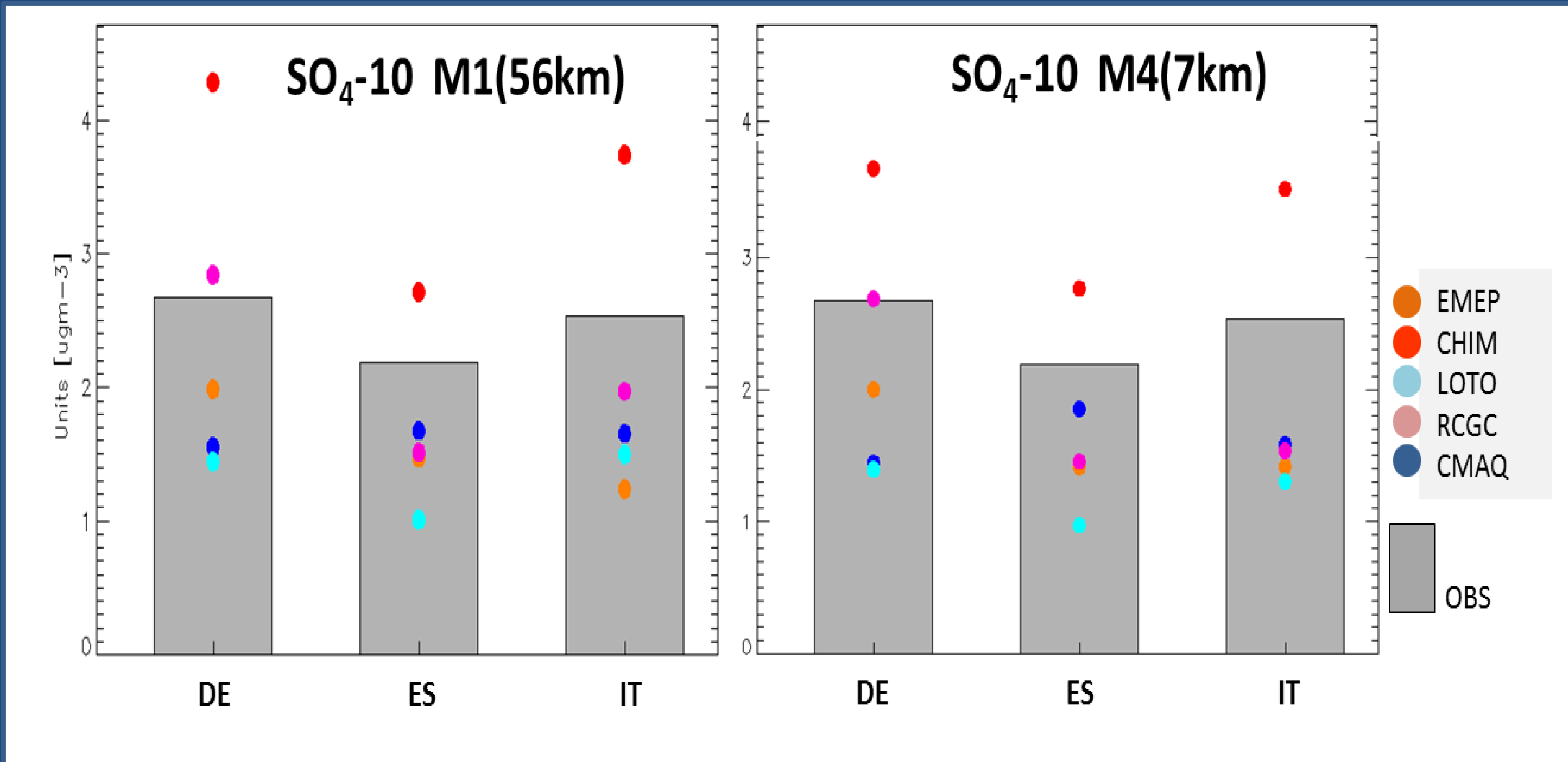
Note the different scales between the station groups

PM10 components
56 km (bars) vs 7 km ■

European Commission



Annual SO_4-10 and OBS 56 km vs 7 km



Conclusions (1)

1. The analysis showed that the grid size does not play a major role for those air quality model calculations which are targeted on the determination of the background (non-urban) air quality.

2. The grid resolution plays an important role in agglomerations characterized by high emission densities. The urban signal, i.e. the concentration difference between high emission areas and their surroundings, usually increases with decreasing grid size.
This grid effect is more pronounced for NO_2 than for PM10, because a large part of the urban PM10 mass consists of secondary components.
This part of the PM10 mass is less affected by a decreasing grid size in contrast to the locally emitted primary components.

Conclusions (2)

3. For all models, increasing model resolution improves the model performance at stations near large conglomerations as reflected by lower biases for PM10, NO_2, and O_3 and increased spatial correlation for NO_2.

4. Improved knowledge on spatial variation in emissions at high resolution is key for the improvement of modelled urban increments. For this purpose one relies on the replacement of currently used top-down European wide data with national expertise.

5. It should be mentioned that there are many benefits to having emission data collected at finer resolution than investigated here. One major reason is that there is a frequent need to re-project emission data in different coordinate systems.
In the near future, for example, there will be a need to run models in either the traditional EMEP polar-stereographic projection, or in longitude-latitude.

Conclusions (3)

6. It is difficult to define a grid size that is adequate to resolve the urban signal under all. Ideally, a grid size in the range of a few km down to 1 km should be chosen. Such a small grid size is not feasible for regional model applications, because the data demands and operating requirements are far too large.

7. If the main emphasis of a model application is targeted on the determination of background air quality for rural areas and large agglomerations, a grid scale of 28km (0.5° Lon and 0.25° Lat) or, if the data and operational requirements can be fulfilled, a grid scale of 14km (0.25° x 0.125°) seems to be a good compromise between a pure background application and an application which reproduces most of the urban signals (7km resolution).

My (personal) choice would be:

0.2^{o} x 0.15^{o} (200x175, 16km x 16km, 1.25 Gb), or

0.1^{0} x 0.075^{0} (400x350, 8km x 8km, 5 Gb)

Final remarks

European Commission

- ScaleDep Exercise: May 2012 (TFMM Malta)
  First results: Sept/Oct 2012
  Workshop Utrecht: Oct 2012
  Final results: Nov/Dec 2012
  Consolidated report: Feb 2013
  Report will appear as EMEP report
- Partners convinced of the importance of this exercise
- Full commitment of the 5 modelling teams
- Availability of Evaluation/Intercomparison Tools at JRC (DeltaTool – Fairmode)
- All data (mod and obs) are available on request
- Subtitle of presentation
  "On the usefulness of TFMM Conference dinners"

END

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