COMPARISON OF COMPUTED AND MEASURED AEROSOL OPTICAL DEPTH (AOD) OVER EUROPE FOR A YEAR LONG CHEMICAL TRANSPORT MODEL SIMULATION

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ARIANET

14th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
Kos Island, Greece, 2-6 October 2011

- ***Is the regional chemical transport model used in this work able to simulate AOD?***

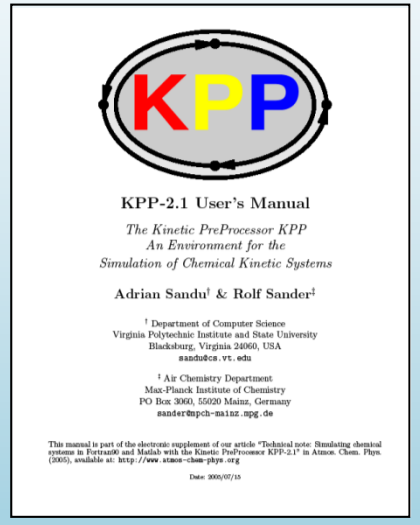
- ***Are AOD results confirmed by PM10 and O_3 predictions (e.g. under/overprediction, seasonal behaviour, …)?***

FARM (Flexible Air quality Regional Model)

Eulerian grid model for dispersion, transformation and deposition of reactive pollutants

- Derived from **STEM-II**, Prof. G.R. Carmichael et al., CGRER (Center for Global and Regional Environmental Research), University of Iowa

- **SAPRC99** gas phase chemical mechanism implemented using KPP (Kinetic PreProcessor, Sandu and Sanders, 2005). **Rosenbrock** (ROS3) solver used for the integration of stiff equations.



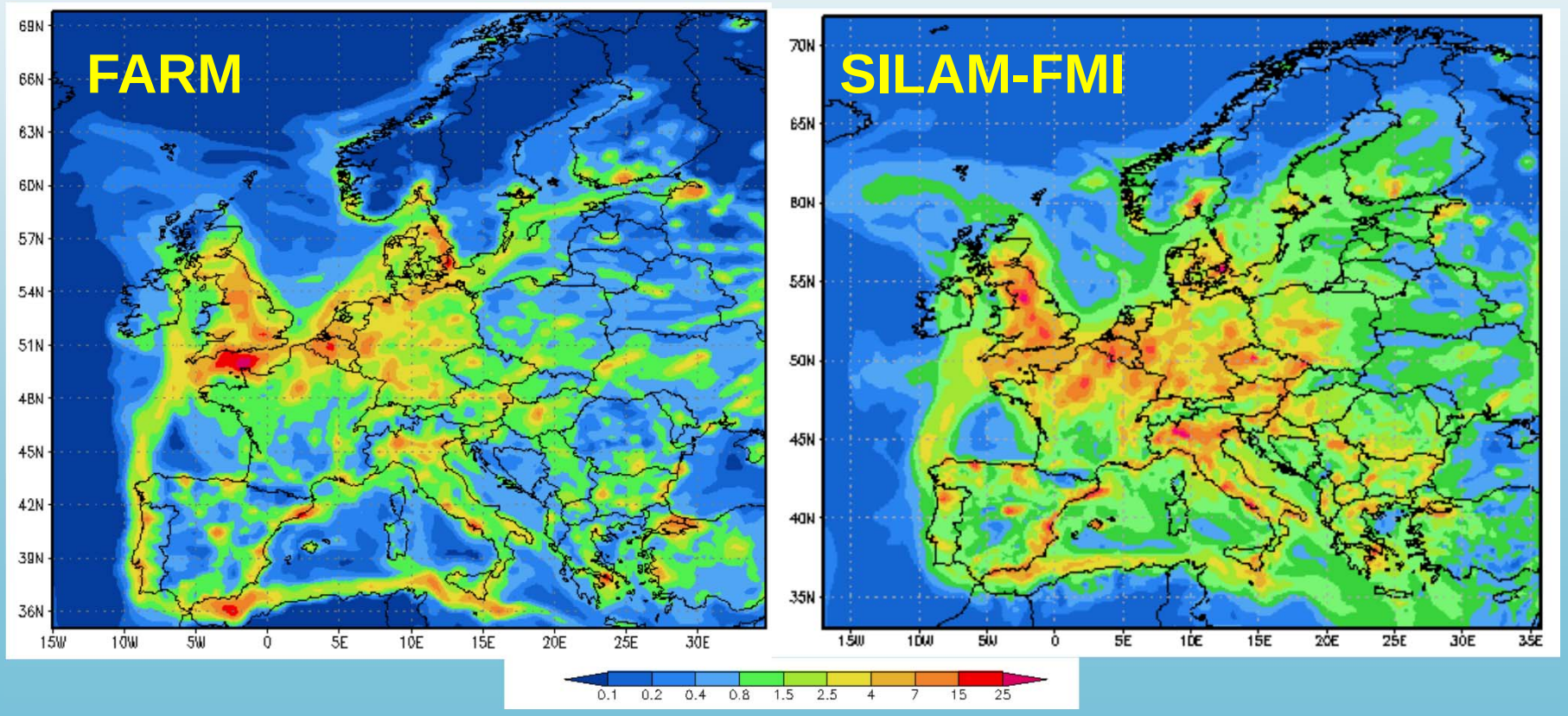
- **aero3** (CMAQ) aerosol module:
  - Lognormal size distributions: ***Aitken mode*** (0.01 -0.1 µm); ***Accumulation mode*** (0.1-2.5 µm) and **Coarse mode** (2.5-10 µm);
  - Aerosol processes: Nucleation; Coagulation; ISORROPIA equilibrium model (SIA); SOA treatment.

MEGAPOLI

Megacities: Emissions, urban, regional and Global Atmospheric POLlution and climate effects, and Integrated tools for assessment and mitigation

SEVENTH FRAMEWORK PROGRAMME

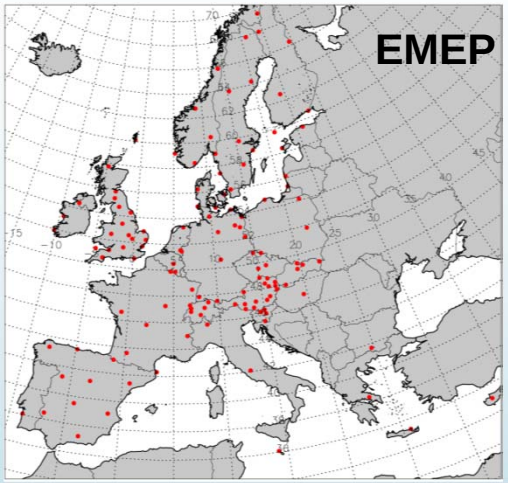
FARM (Flexible Air quality Model) participated to MEGAPOLI regional multi-model ensemble (CHIMERE, CMAQ, FARM, SILAM-FMI, LOTOS-EUROS) and intercomparison of model results. Benchmark test case: full year 2005.

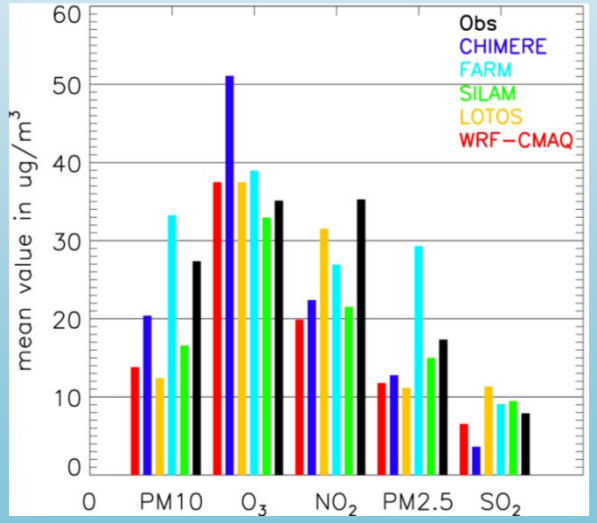


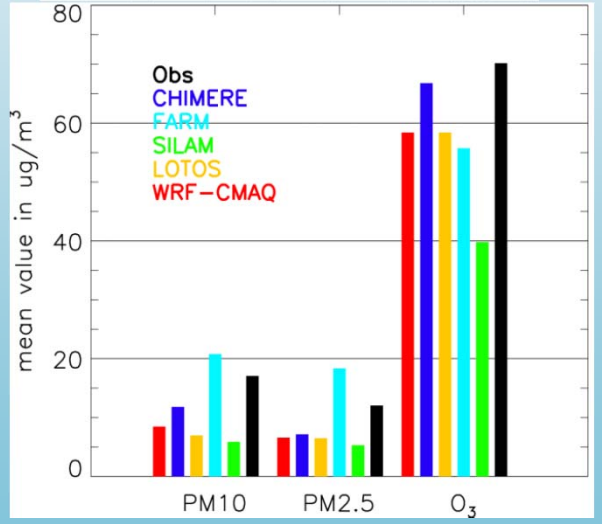
1.7.2009, NO_2 near-surface concentrations from FARM and SILAM-FMI

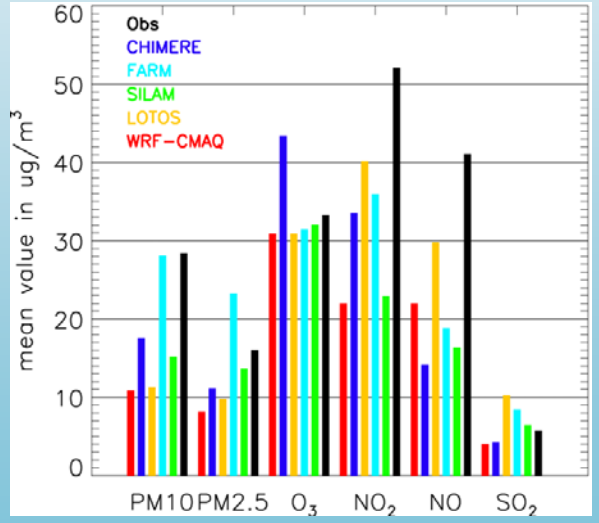
MEGAPOLI regional ensemble for year 2005

Operational evaluation: Annual means









Evaluation of concentration simulations for remote and two urban areas

Michael Haller, *K. Heinke Schlünzen, G. Bedbur, K. Conrady, S. Finardi, S. Gimmerthal, D. Grawe, P. Hoffmann, M. Prank, V. Reinhardt, A. Segers, C. Silibello, G. Siour, M. Sofiev, R. Sokhi, M. Uphoff, J. Theloke, X. Vazhappilly-Francis*

11 EMS, 12 – 16 September 2011, Berlin

FARM modelled concentrations agree with other models simulation results (higher PM concentrations) !

MEGAPOLI regional ensemble for year 2005

FARM runs CONFIGURATION

Spatial resolution:

- 25 km (horizontal); 16 levels, up to 10 km (vertical)

Emissions:

- **Anthropogenic:** TNO data set (~ 7 km resolution);
- **Biogenic/natural:**
  - Isoprene and Terpenes from vegetation (Guenther *et al.*, 1993);
  - PM (fine and coarse) from Aeolian resuspension (Vautard *et al.*, 2005);
  - sea salts, wind influence (Zhang *et al.*, 2005).

Meteorology:

- **ECMWF** analysis;

IC/BC:

- **MPI MATCH – Global scale:** gaseous species
- **GOCART – Global scale:** aerosols, Climatological fields

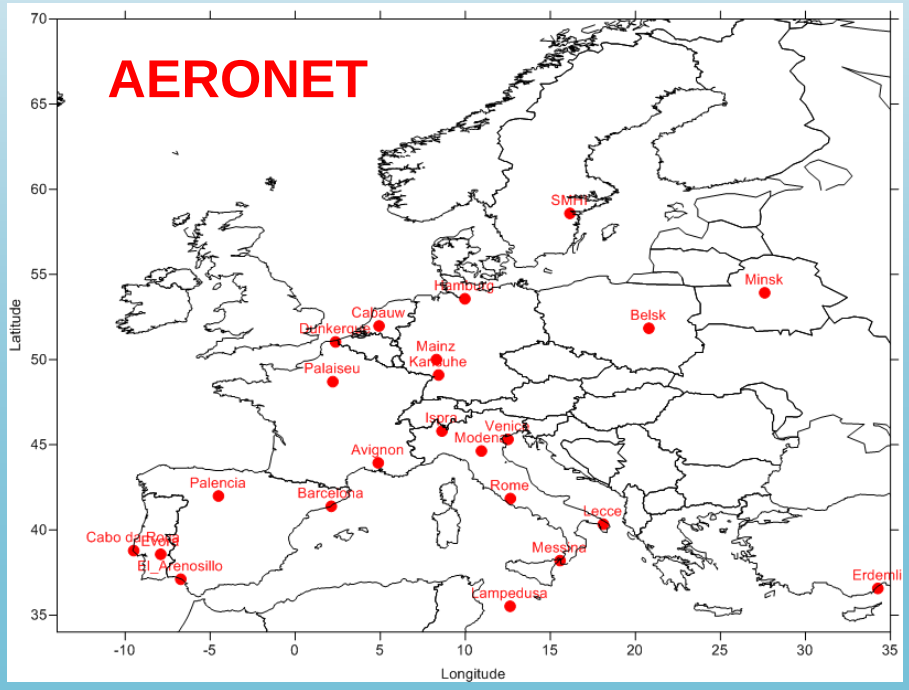
AOD analysis

The aerosol module ***aero3*** model does not include coarse mode particles in its visual range calculations. AOD (Aerosol Optical Depth), a dimensionless quantification of visibility impairment, is defined by the following equation:

$$AOD = \int_{z=0}^{z_{top}} B_{sp}\, dz$$

where B_{sp} is the aerosol extinction coefficient in km^{-1} and z is altitude in km. B_{sp} is calculated through the extinction efficiency, a measure of light scattering efficiency, which in turn is estimated using approximations to the Mie theory (Binkowski, 1999).

To evaluate the model predicted columnar AOD against observations we have used data from MODIS satellite sensor and sun photometer measurements of the direct (collimated) solar radiation (AERONET network).

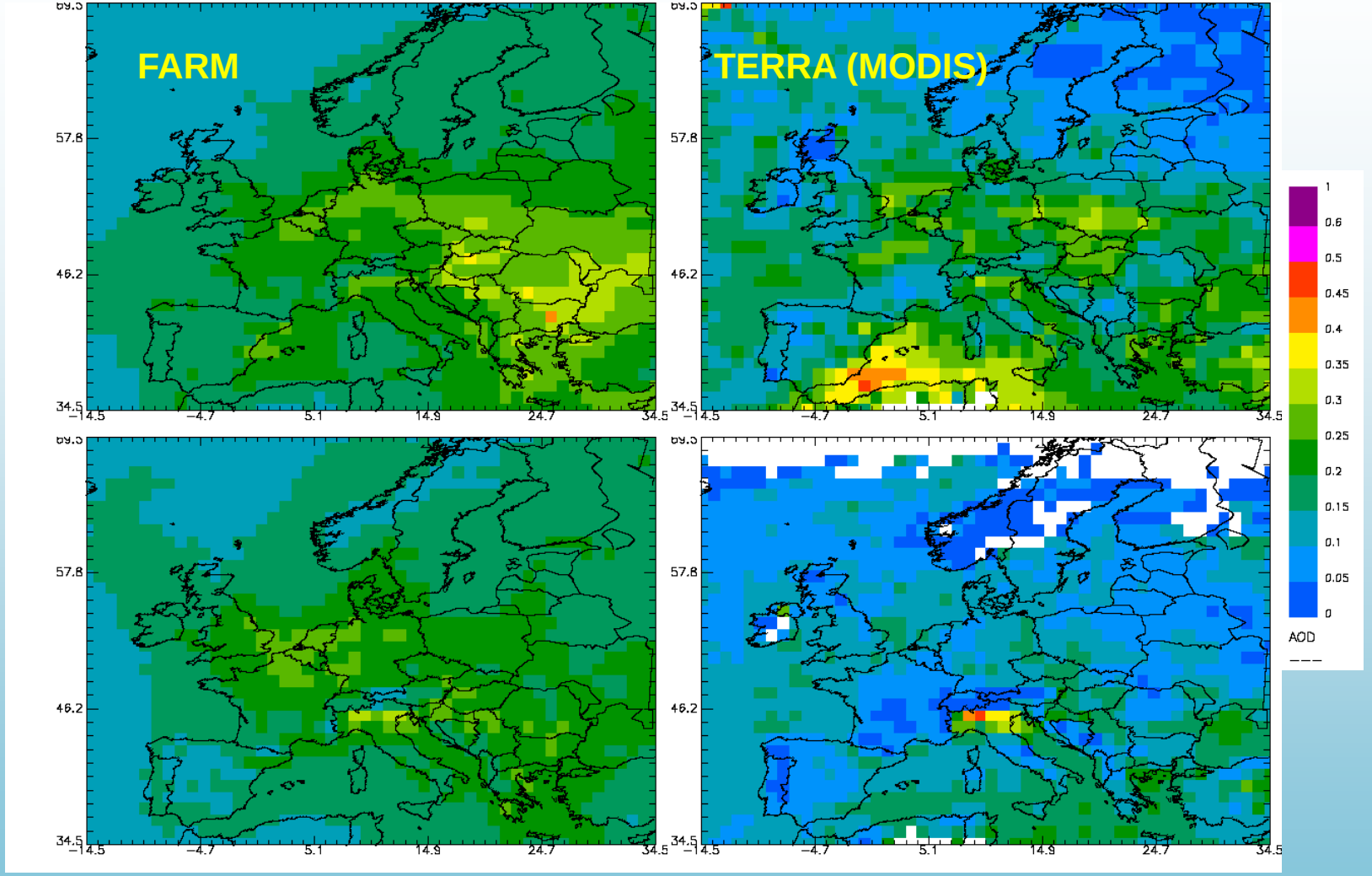


AOD analysis

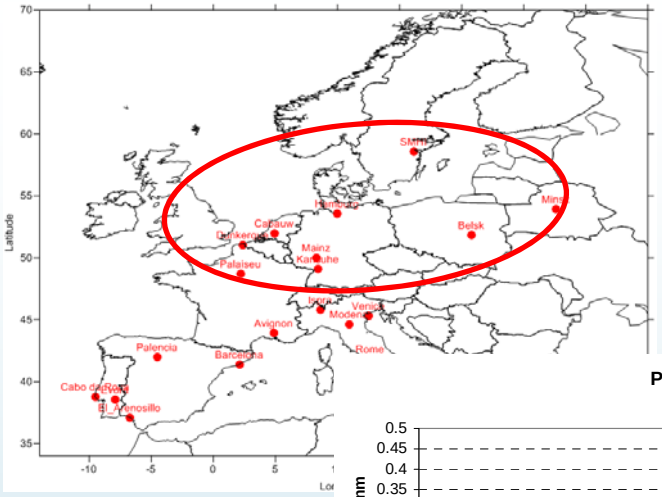
Monthly averages

July

Oct.



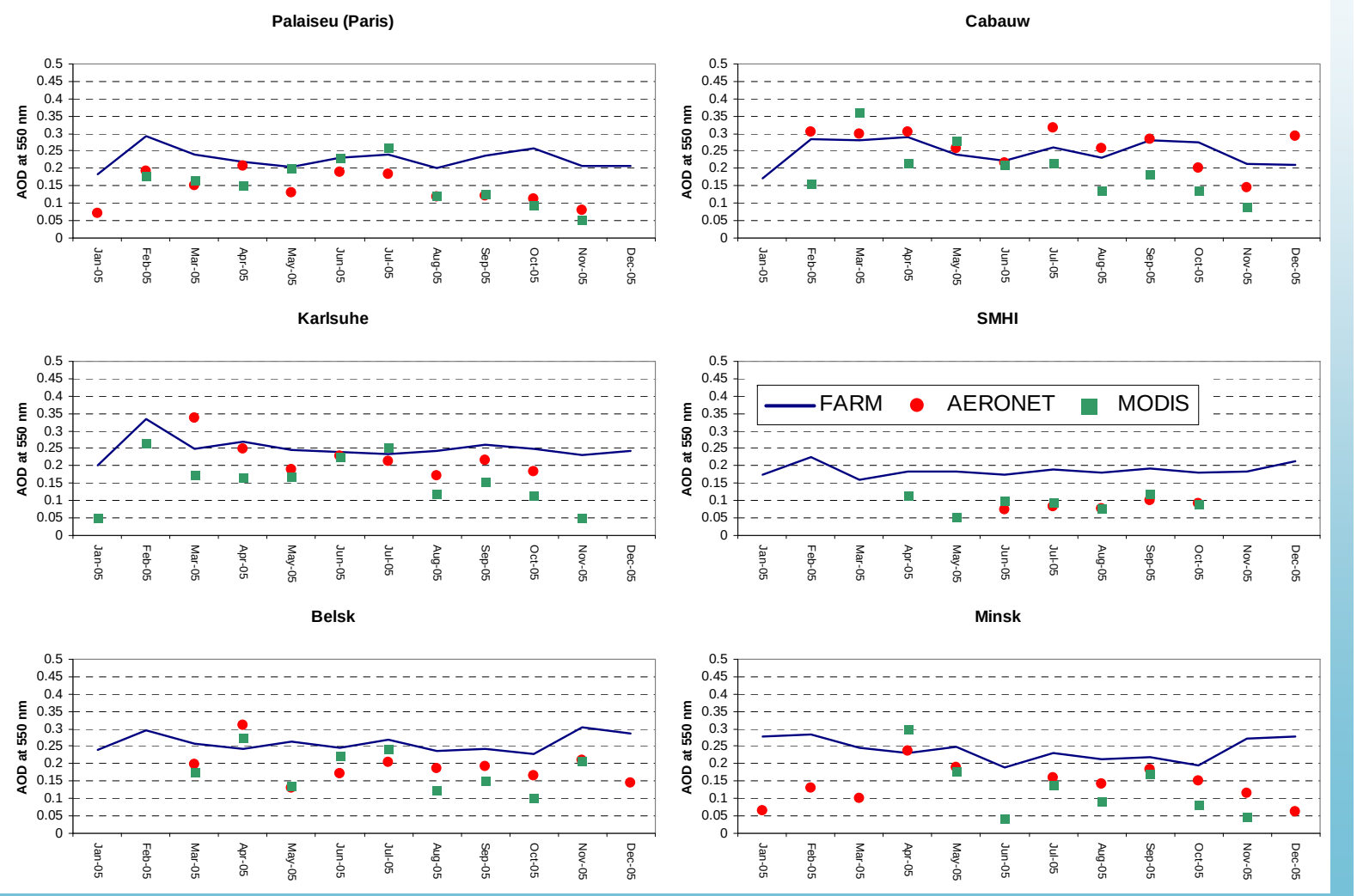
- ***To be consistent with the TERRA orbit tracks over Central Europe, simulated monthly AOD are computed from daily 6-hour running averaged fields extracted at noon;***
- ***Monthly AOD fields from TERRA may be not consistent with modelled ones due to missing data;***
- ***FARM simulations does not take into account contributions from Saharan dust.***

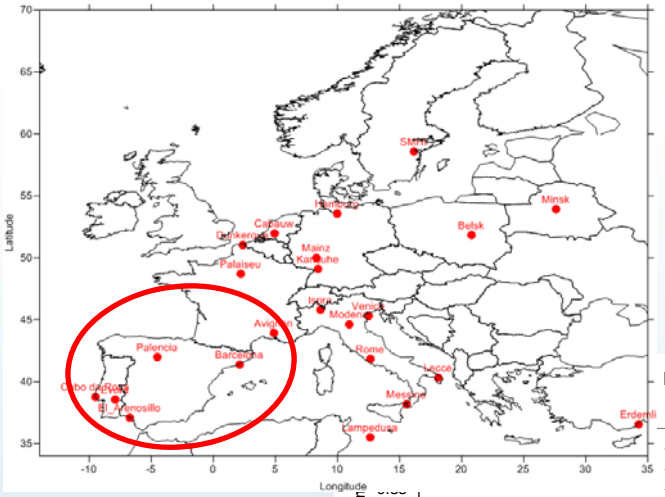


AOD analysis

Monthly averages

FARM vs MODIS & AERONET data





AOD analysis

Monthly averages

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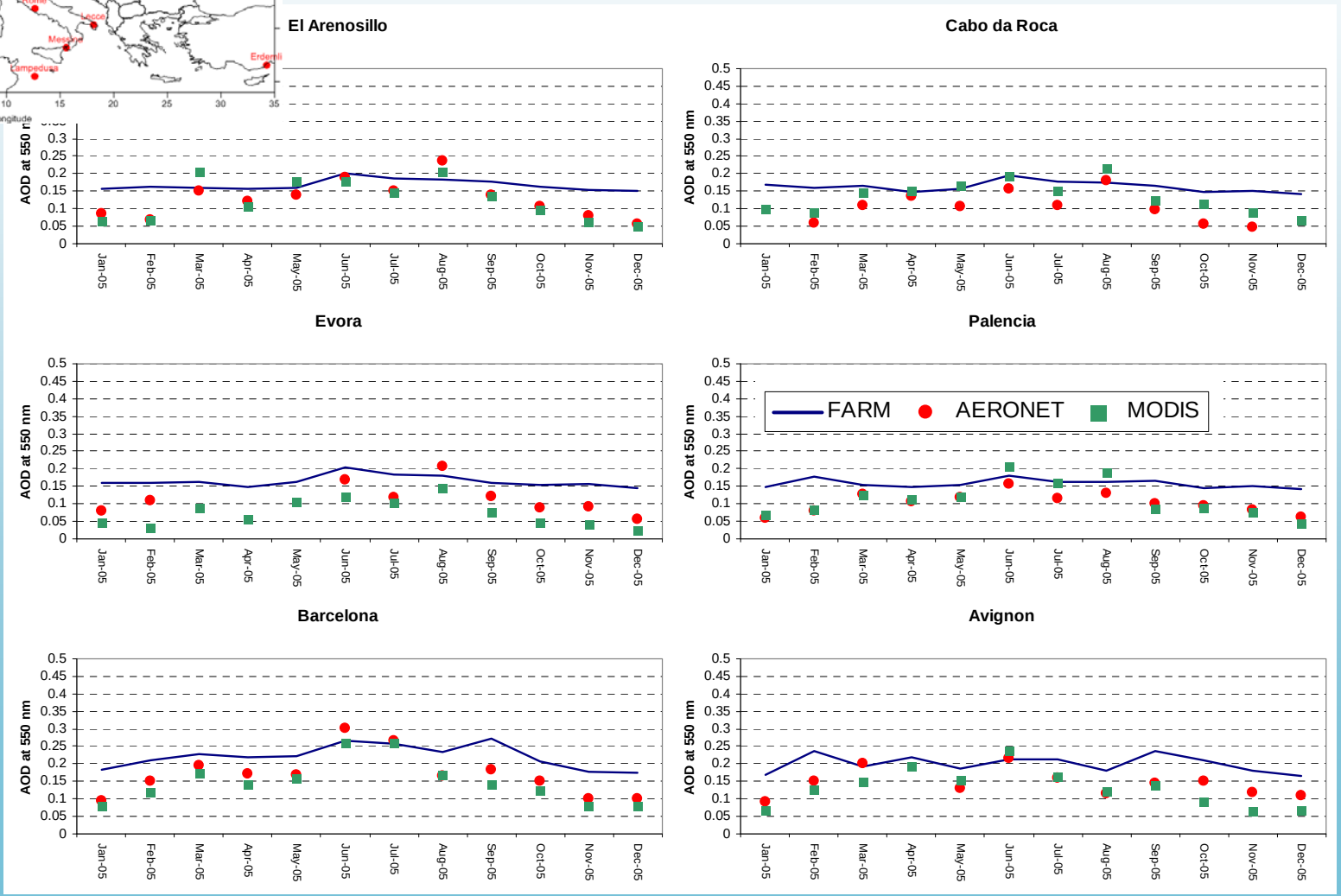
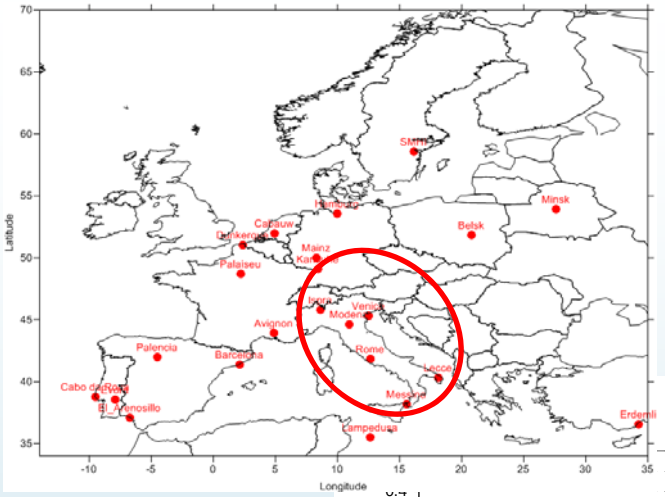
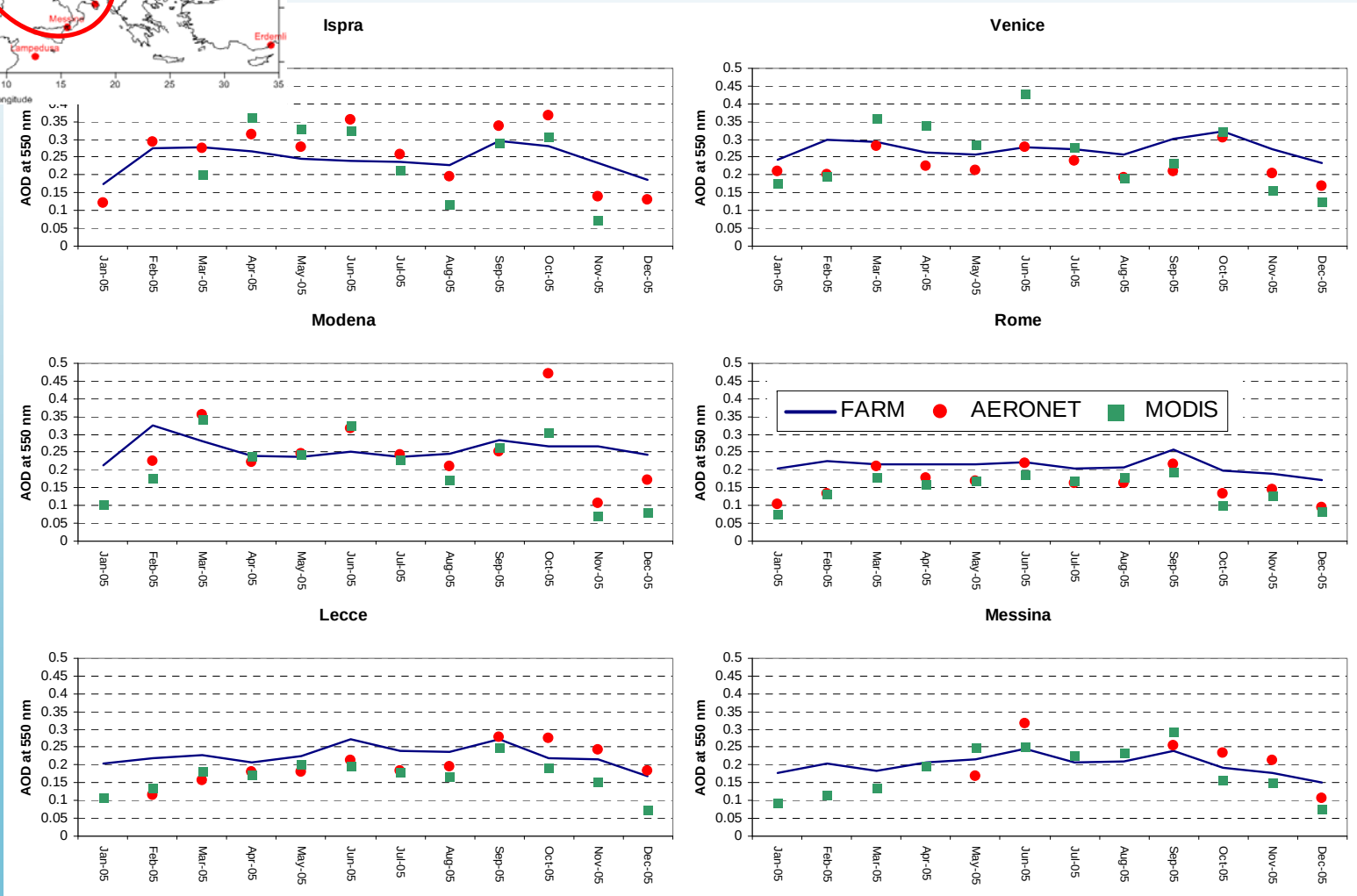


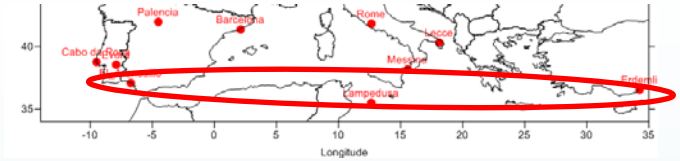


AOD analysis

Monthly averages

FARM vs MODIS & AERONET data



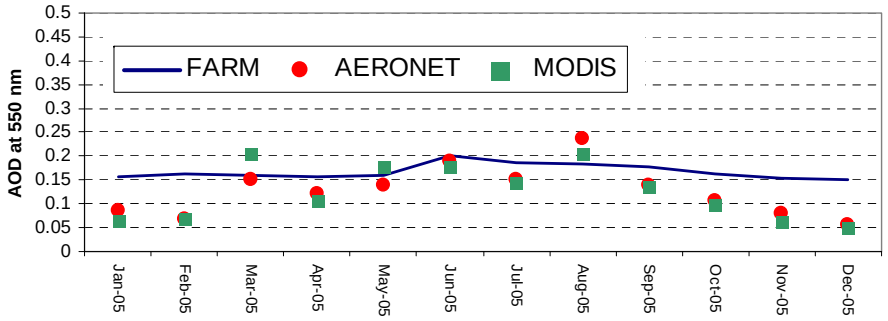


AOD analysis

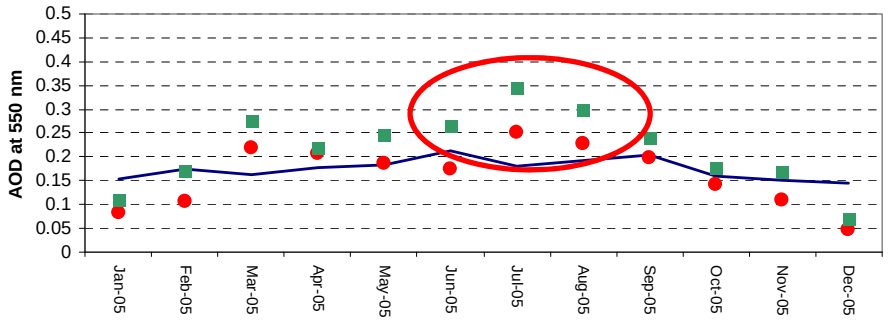
Monthly averages

FARM vs MODIS & AERONET data

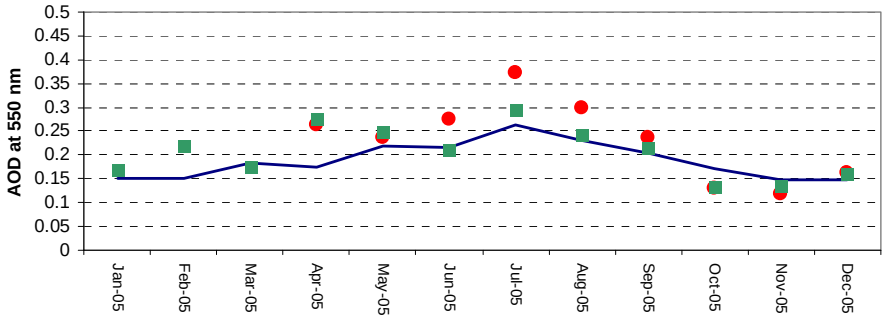
El Arenosillo



Lampedusa



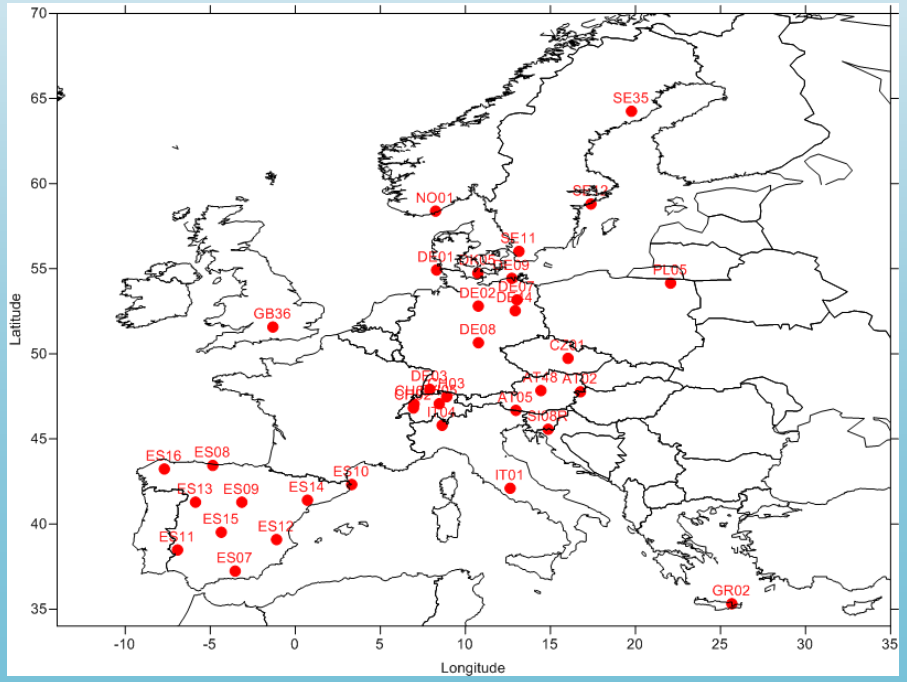
Erdemli



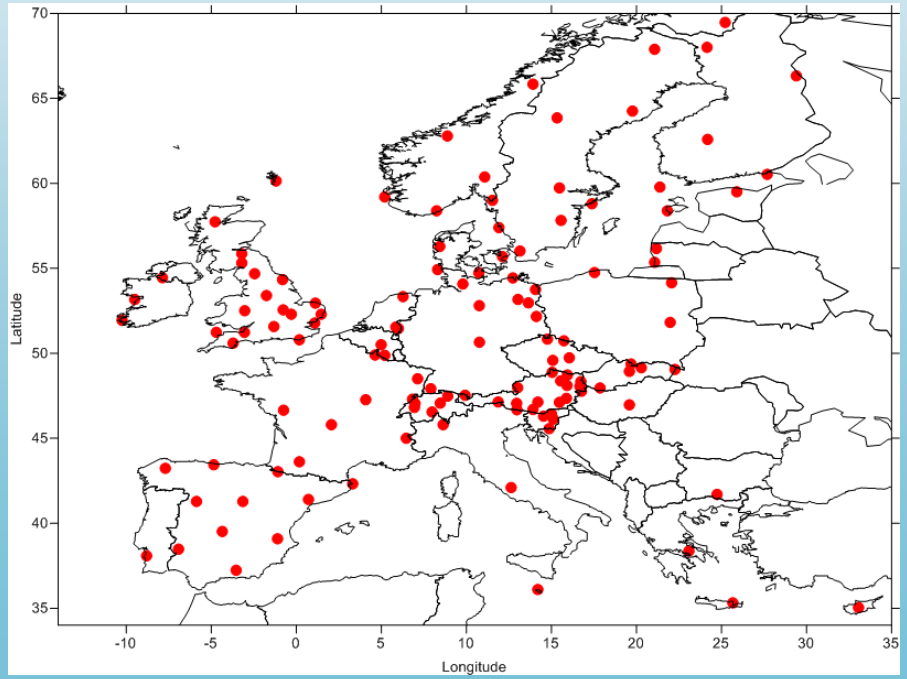
FARM simulations does not take into account contributions from Saharan dust

PM_{10} and ozone model performances
FARM vs EMEP stations
(http://tarantula.nilu.no/projects/ccc/emepdata.html)

PM_{10}



O_3



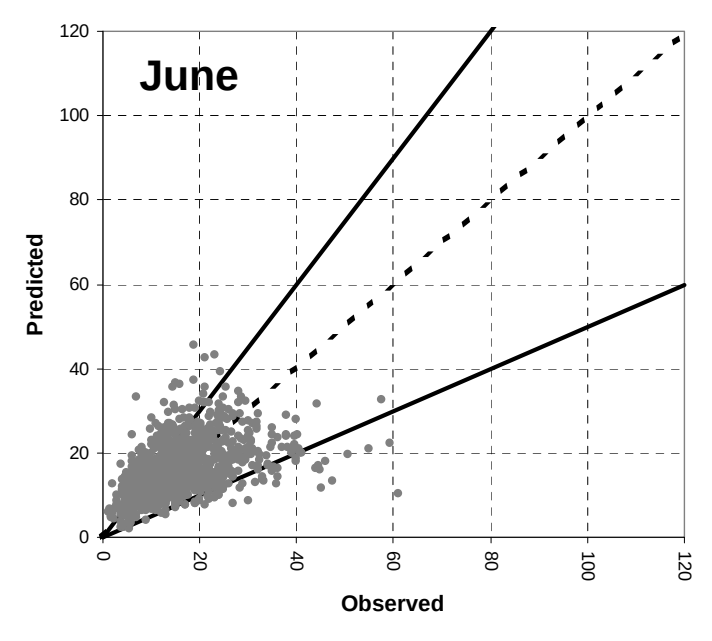
Measures used to calculate overall model performances

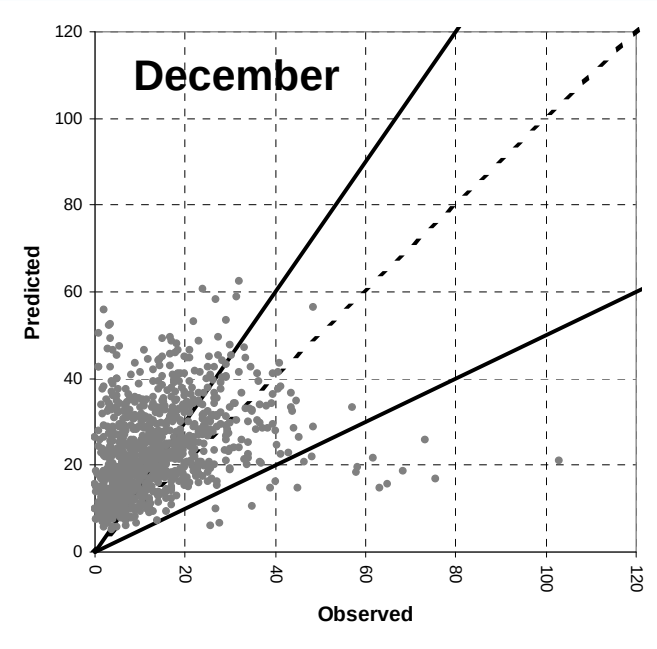
Regional scale performance criteria (P.C.) and goals (G.) for some statistical indicators (from Thunis *et al.*, 2011).

Performance Metrics	Range	O_3		PM_{10}		Equation
		P.C.	G.	P.C.	G.	
Correlation coefficient (R)	*-1 to 1*	0.65	0.78	0.40	0.48	$R = \frac{\frac{1}{N}\sum_{i=1}^{N}\left(P_i - \overline{P}\right)\cdot\left(O_i - \overline{O}\right)}{\sigma_P \sigma_O}$
Mean Fractional Bias (MFB)	*-200 to +200 %*	| 30 |	| 15 |	| 60 |	| 30 |	$MFB = \frac{1}{N}\sum_{i=1}^{N}\frac{\left(P_i - O_i\right)}{\left(\frac{P_i + O_i}{2}\right)}\cdot 100$
Mean Fractional Error (MFE)	*0 to +200 %*	45	30	75	50	$MFE = \frac{1}{N}\sum_{i=1}^{N}\frac{\left\|P_i - O_i\right\|}{\left(\frac{P_i + O_i}{2}\right)}\cdot 100$
Fraction of prediction within a Factor of 2 of observations (FAC2)	*0 to +100 %*	50	60	50	60	$FAC2 = \left(\frac{1}{N}\sum_{i=1}^{N} i \left\| \left(0.5 \le \frac{P_i}{O_i} \le 2\right)\right.\right)\cdot 100$

Thunis P., E. Georgieva, A. Pederzoli, 2011: The DELTA tool and Benchmarking Report template Concepts and User's Guide, Joint Research Centre, Ispra
available at: http://fairmode.ew.eea.europa.eu/models-benchmarking-sg4

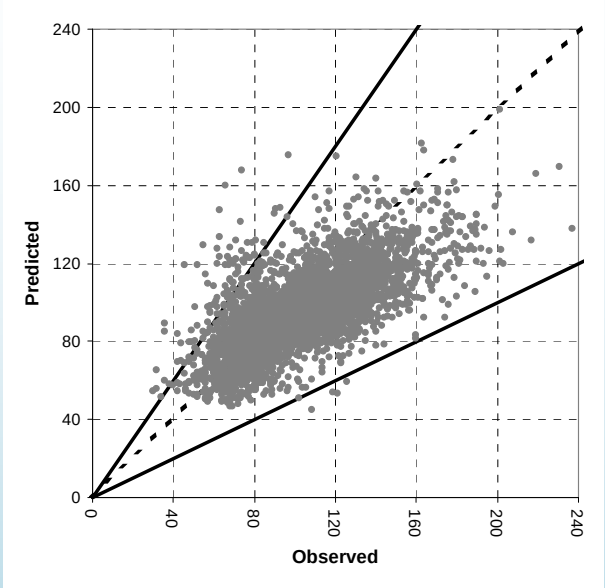
PM_{10}
daily average performances



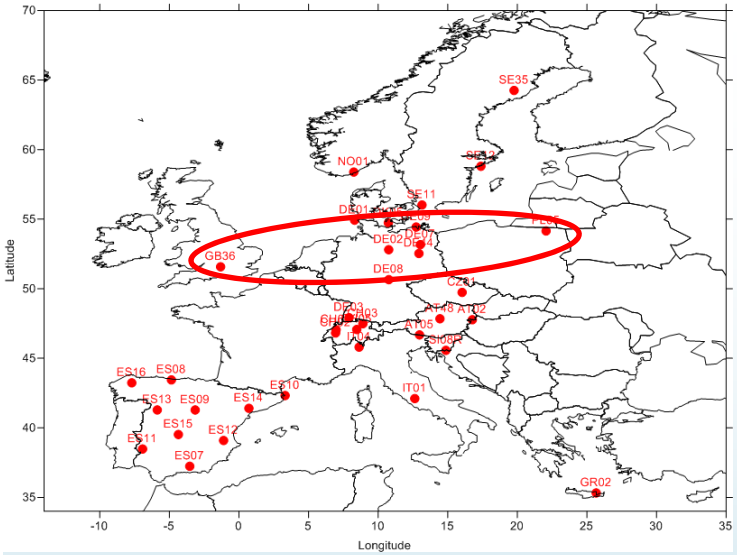


Performance Metrics	Range	PM_{10}			
		P.C.	G.	June	Dec.
Correlation coefficient (R)	*-1 to 1*	0.40	0.48	0.44	0.32
Mean Fractional Bias (MFB)	*-200 to +200 %*	| 60 |	| 30 |	1.14	16.27
Mean Fractional Error (MFE)	*0 to +200 %*	75	50	9.16	18.63
Fraction of prediction within a factor of 2 of observations (FAC2)	*0 to +100 %*	50	60	86.12	47.57

O_3
1 hour maximum performances (June)



Performance Metrics	Range	O_3		
		P.C.	G.	June
Correlation coefficient (R)	*-1 to 1*	0.65	0.78	0.70
Mean Fractional Bias (MFB)	*-200 to +200 %*	| 30 |	| 15 |	-1.64
Mean Fractional Error (MFE)	*0 to +200 %*	45	30	4.27
Fraction of prediction within a factor of 2 of observations (FAC2)	*0 to +100 %*	50	60	99.54



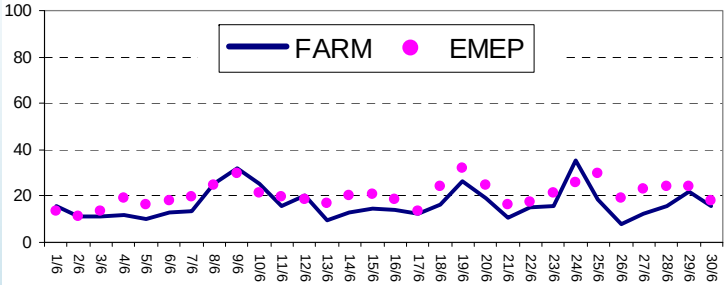
PM_{10} Daily averages

FARM vs EMEP data

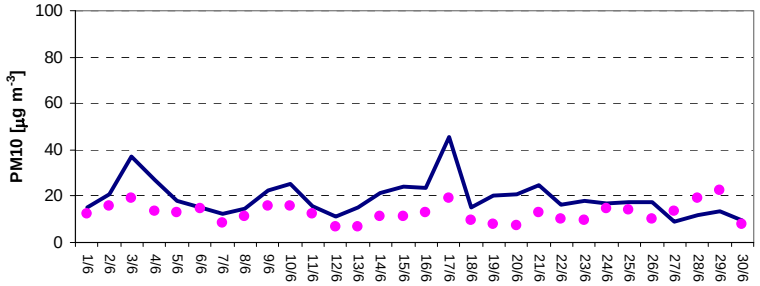
(from 54.4 to 51.6 Lat)

June

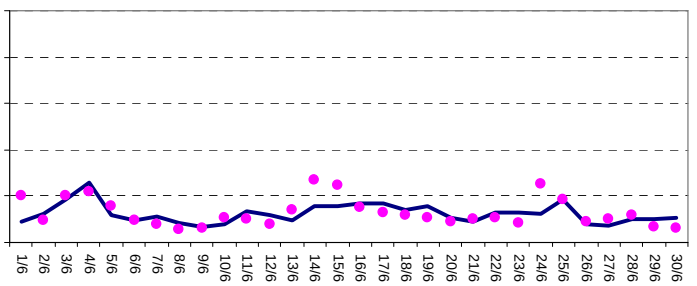
Harwell (GB) - (lon. -1.32,lat. 51.57,alt. 137)



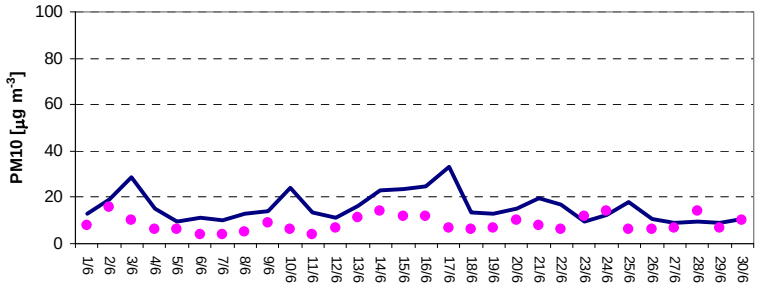
Zingst (DE) - (lon. 12.73,lat. 54.43,alt. 1)



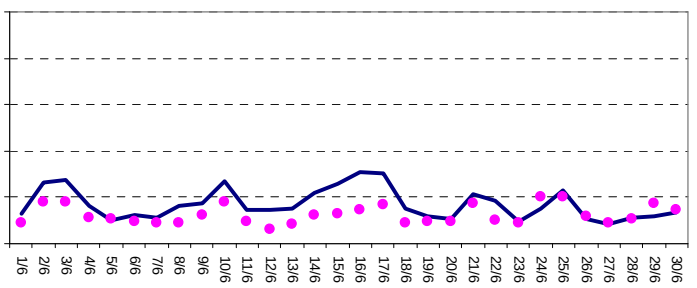
Diabla Gora (PL) - (lon. 22.07,lat. 54.15,alt. 157)

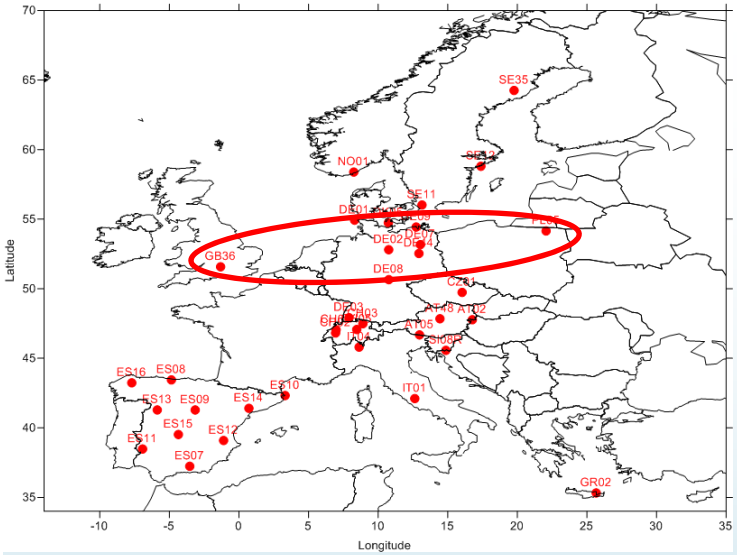


Neuglobsow (DE) - (lon. 13.03,lat. 53.17,alt. 62)



Langenbrügge (DE) - (lon. 10.76,lat. 52.80,alt. 74)



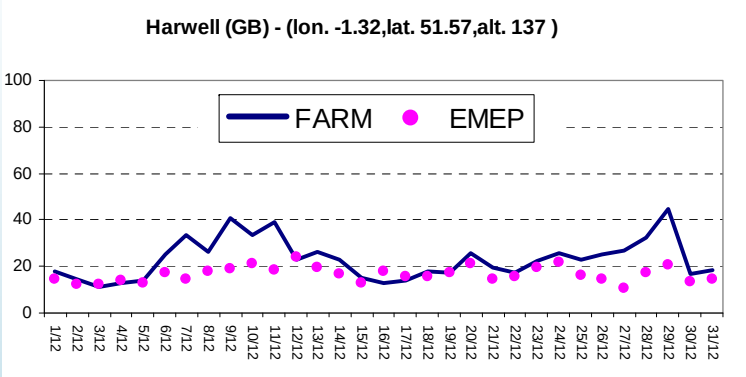


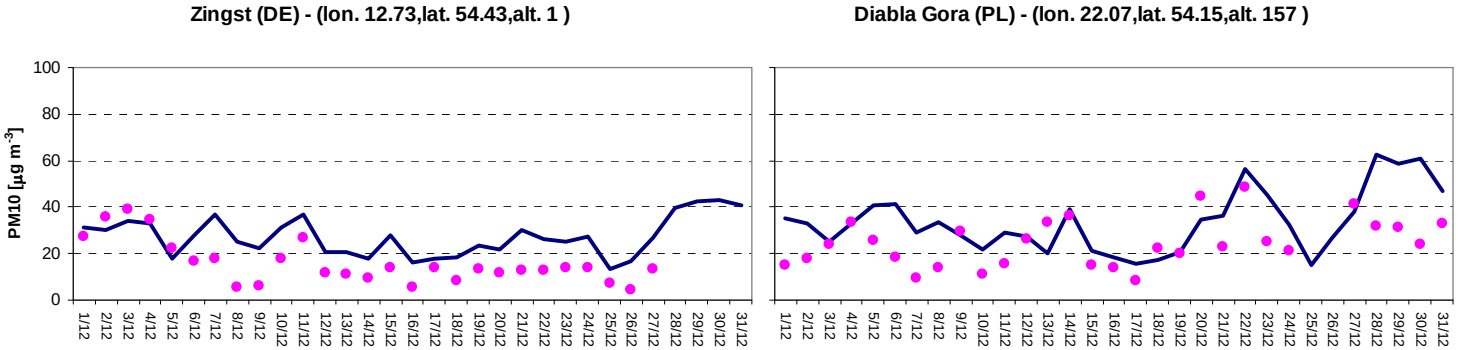
PM_{10} Daily averages

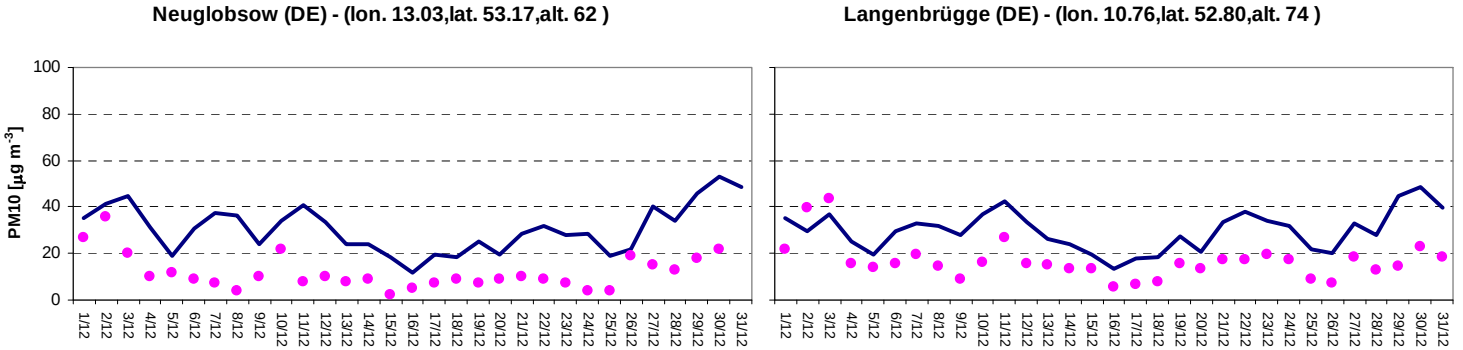
FARM vs EMEP data

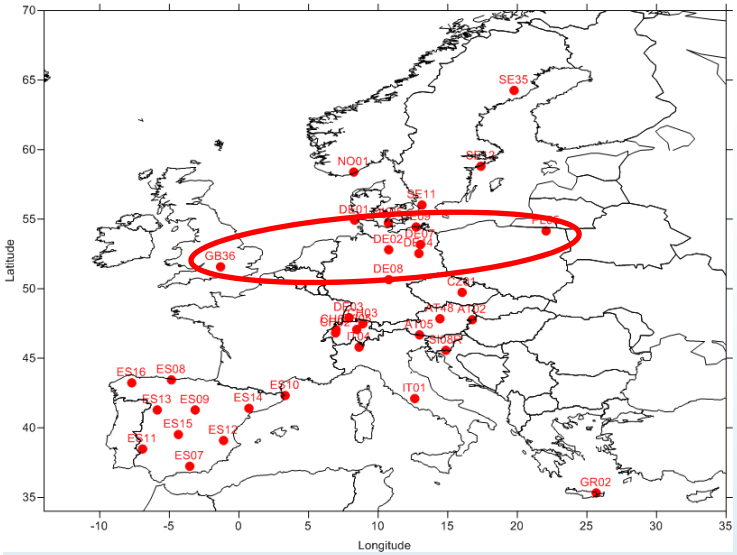
(from 54.4 to 51.6 Lat)

December







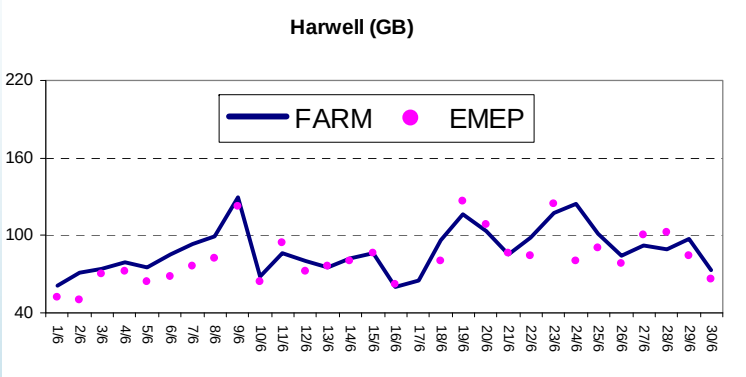


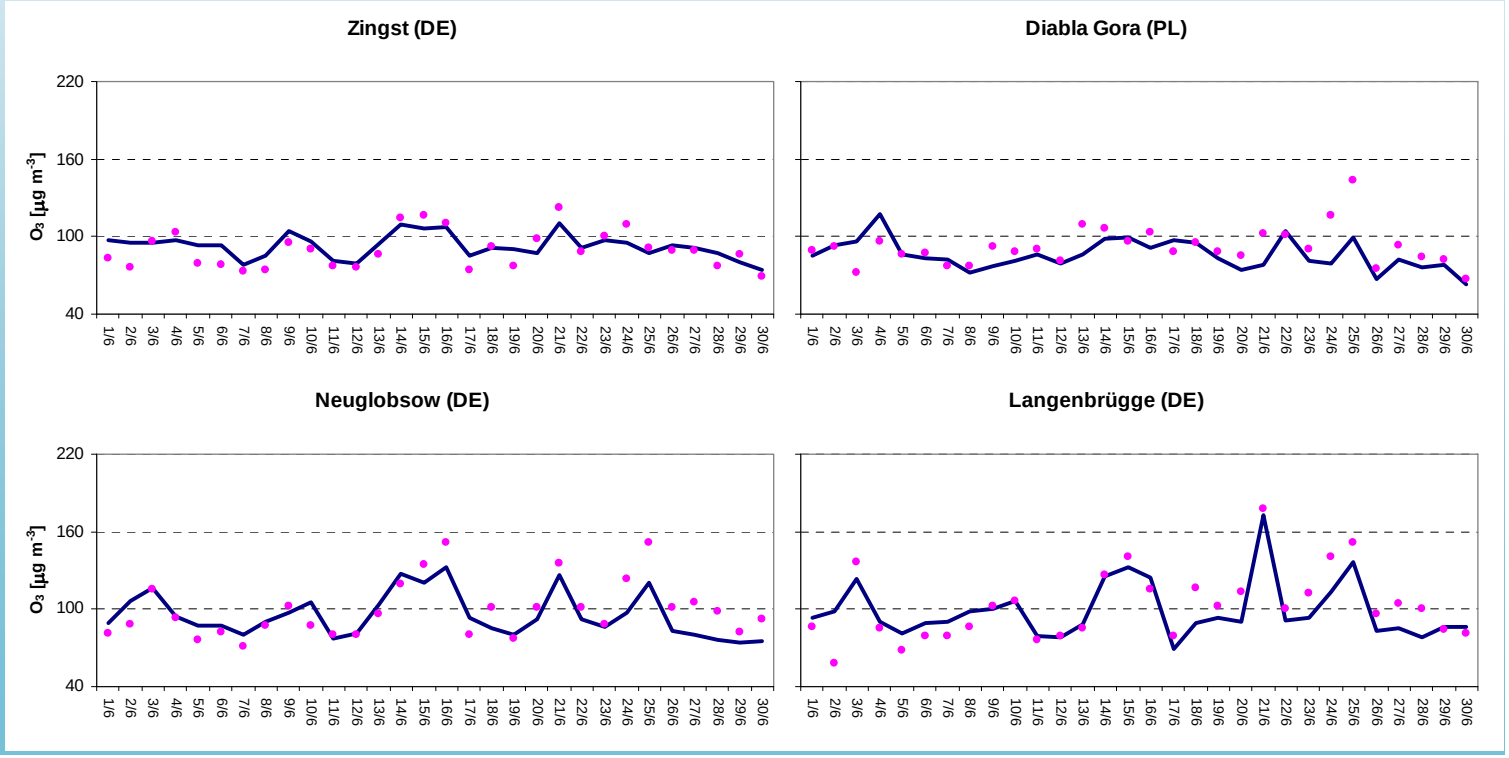
O_3 Daily maxima

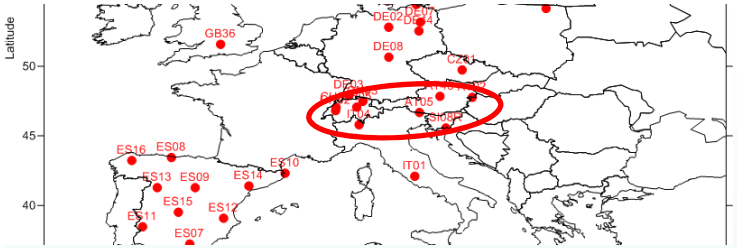
FARM vs EMEP data

(from 54.4 to 51.6 Lat)

June







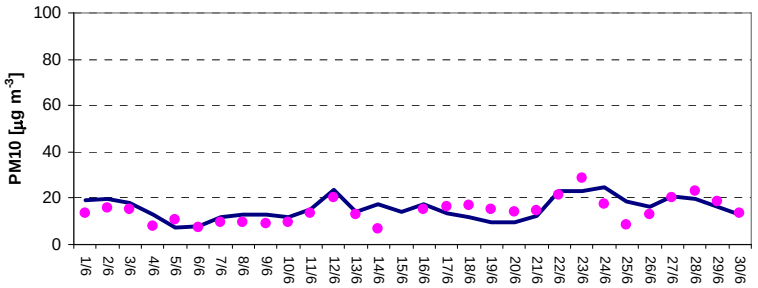
PM_{10} Daily averages

FARM vs EMEP obs.

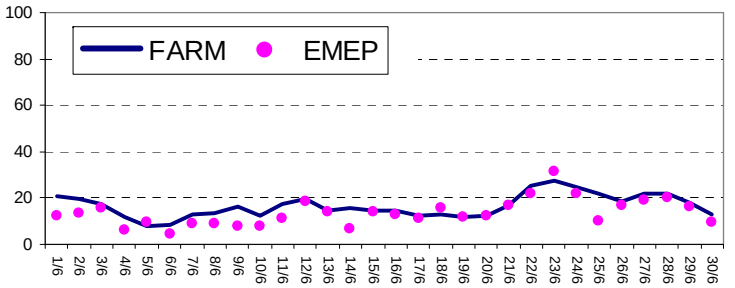
(from 47.1 to 45.6 Lat)

June

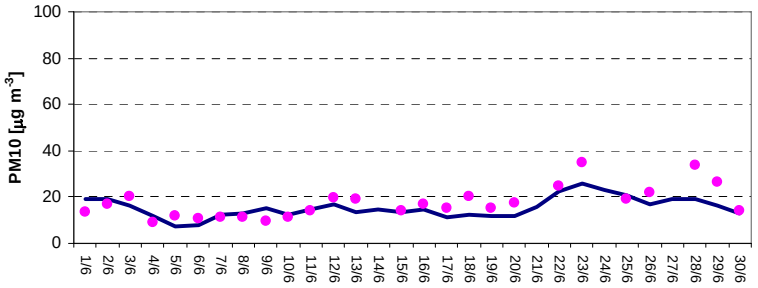
Rigi (CH) - (lon. 8.46,lat. 47.07,alt. 1031)



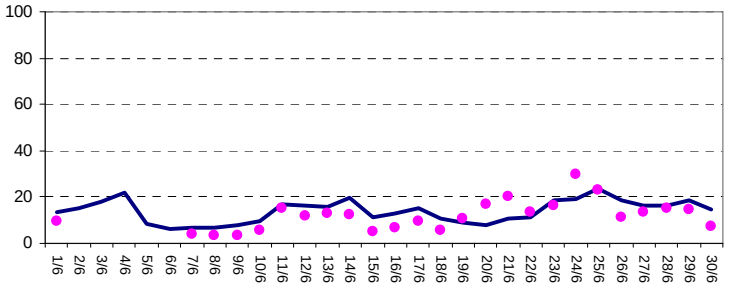
Chaumont (CH) - (lon. 6.98,lat. 47.05,alt. 1137)



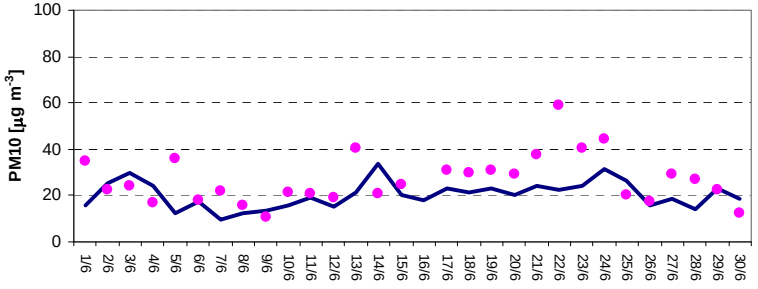
Payerne (CH) - (lon. 6.94,lat. 46.81,alt. 489)



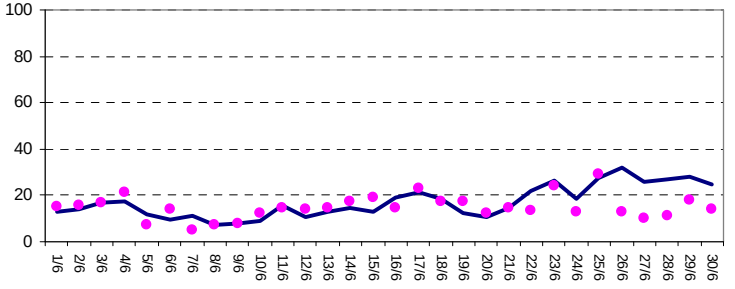
Vorhegg (AT) - (lon. 12.97,lat. 46.68,alt. 1020)

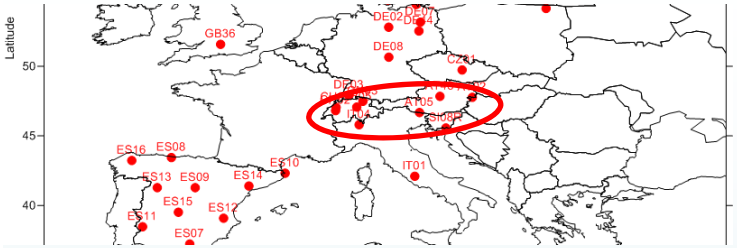


Ispra (IT) - (lon. 8.63,lat. 45.80,alt. 209)



Iskrba (SI) - (lon. 14.87,lat. 45.57,alt. 520)





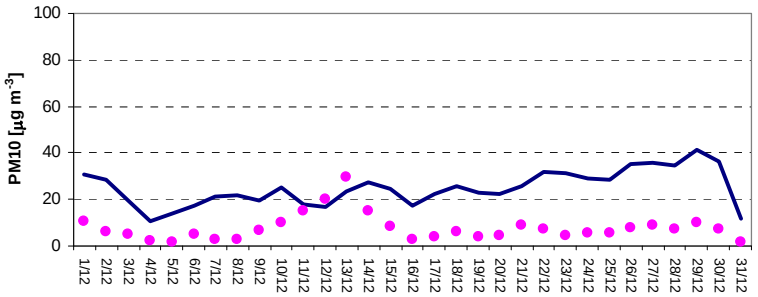
PM_{10} Daily averages

FARM vs EMEP obs.

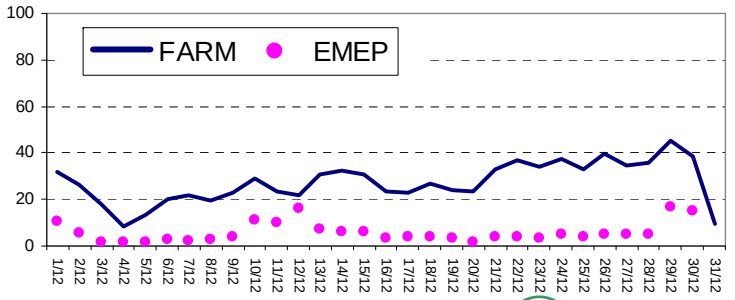
(from 47.1 to 45.6 Lat)

December

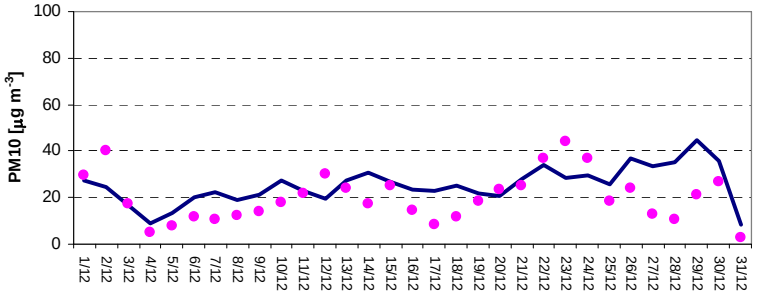
Rigi (CH) - (lon. 8.46,lat. 47.07,alt. 1031)



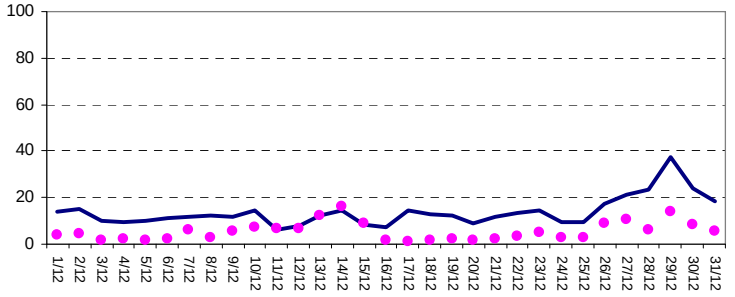
Chaumont (CH) - (lon. 6.98,lat. 47.05,alt. 1137)



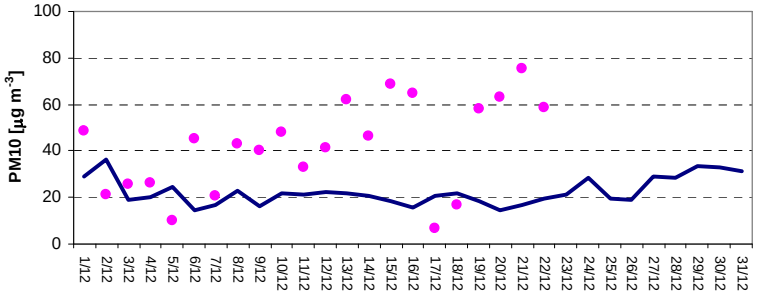
Payerne (CH) - (lon. 6.94,lat. 46.81,alt. 489)



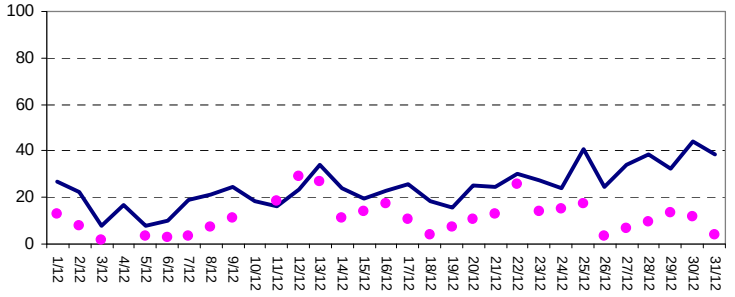
Vorhegg (AT) - (lon. 12.97,lat. 46.68,alt. 1020)

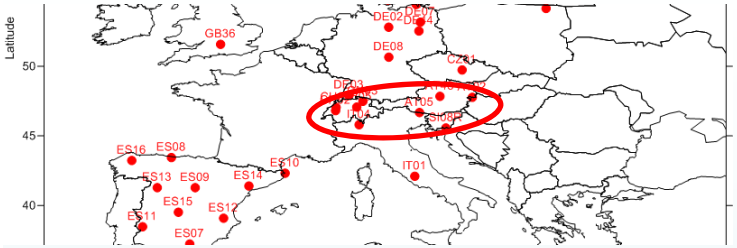


Ispra (IT) - (lon. 8.63,lat. 45.80,alt. 209)



Iskrba (SI) - (lon. 14.87,lat. 45.57,alt. 520)





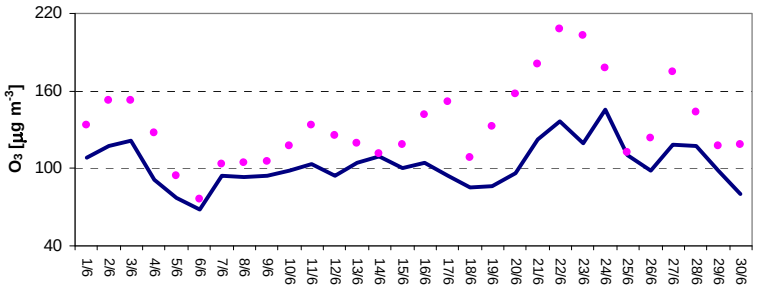
O_3 Daily maxima

FARM vs EMEP obs.

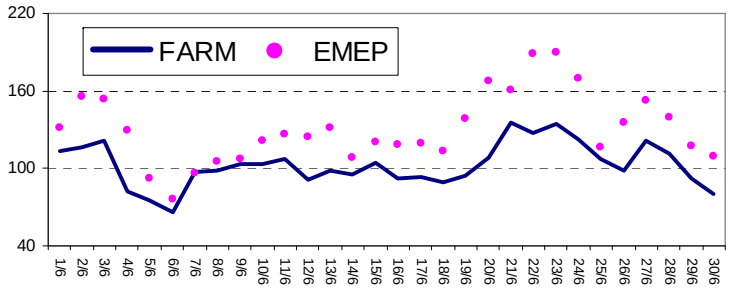
(from 47.1 to 45.6 Lat)

June

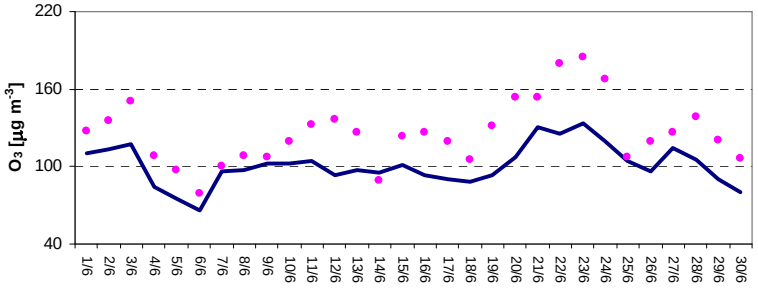
Rigi (CH) **Alt. 1031 m**



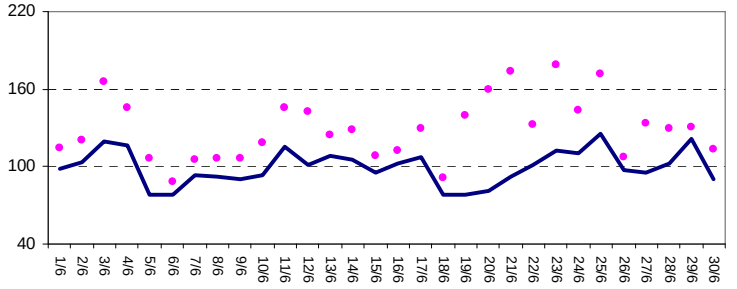
Chaumont (CH) **Alt. 1137 m**



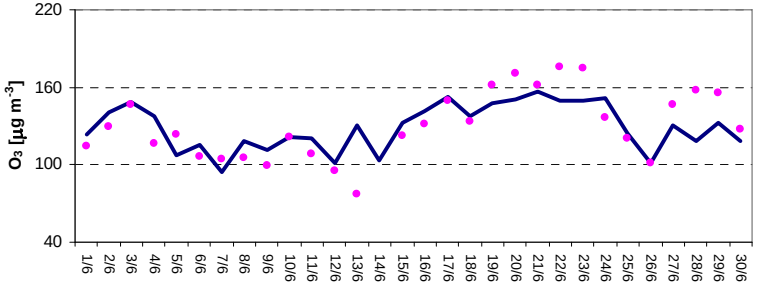
Payerne (CH) **Alt. 489 m**



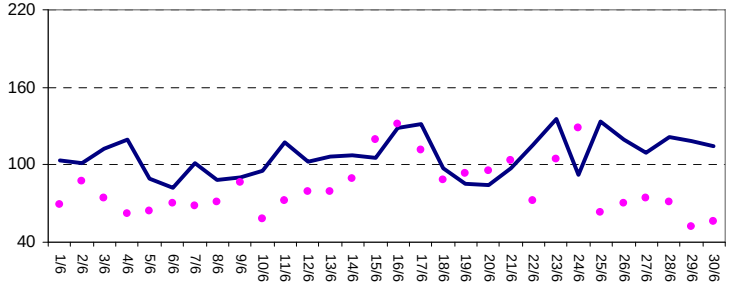
Vorhegg (AT) **Alt. 1020 m**



Ispra (IT)



Iskrba (SI)



Comments

Is FARM model (CTM) able to simulate AOD?

- **AOD (monthly average)**: the evaluation has evidenced a **better agreement** between observed and modelled data during **warmer seasons** and an **overestimation** of measured data during **colder** periods particularly at **northerly sites**.

Are AOD results confirmed by PM10 predictions (e.g. under/overpredictions, seasonal behaviour, …)?

The comparison between observed and predicted PM_{10} and ozone concentrations confirms AOD results:

- **PM_{10} (daily average)**: the evaluation has evidenced a **better agreement** between observed and modelled data during **warmer season** and an **overestimation** of measured data during **colder** periods particularly at **elevated alpine sites**;

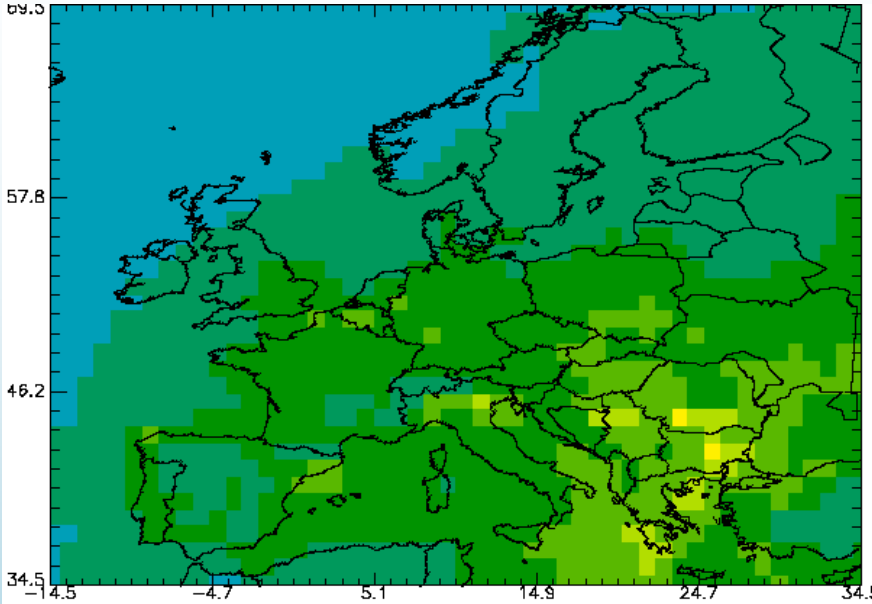
- **Ozone (daily maximum)**: **good agreement** between observed and predicted levels for the **June simulation, difficulties** to simulate **peaks** particularly at **elevated alpine sites** (Coherent with Haller's results - not presented here - Underestimation of high O_3 concentrations by the five models).

The possible reasons of the seasonal PM and AOD biases are presently under investigation

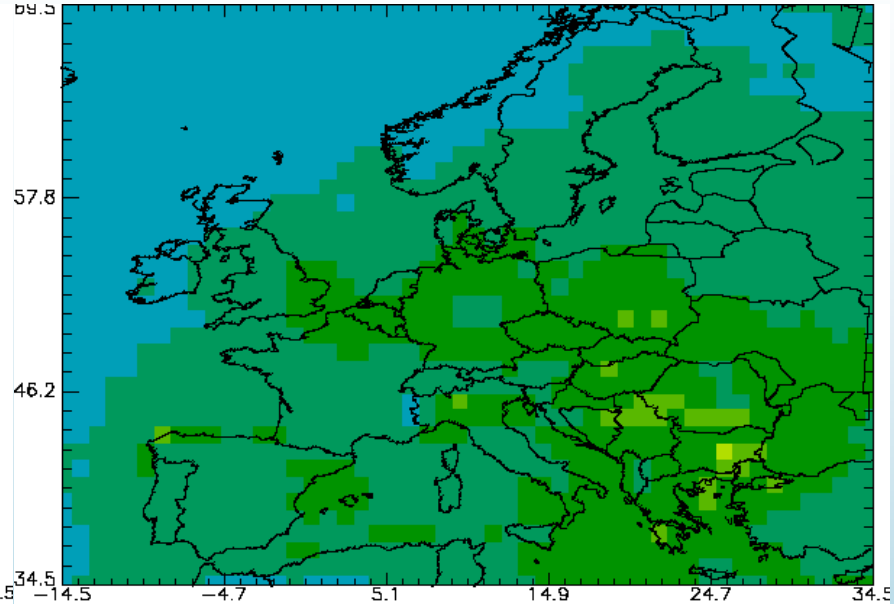
AOD analysis

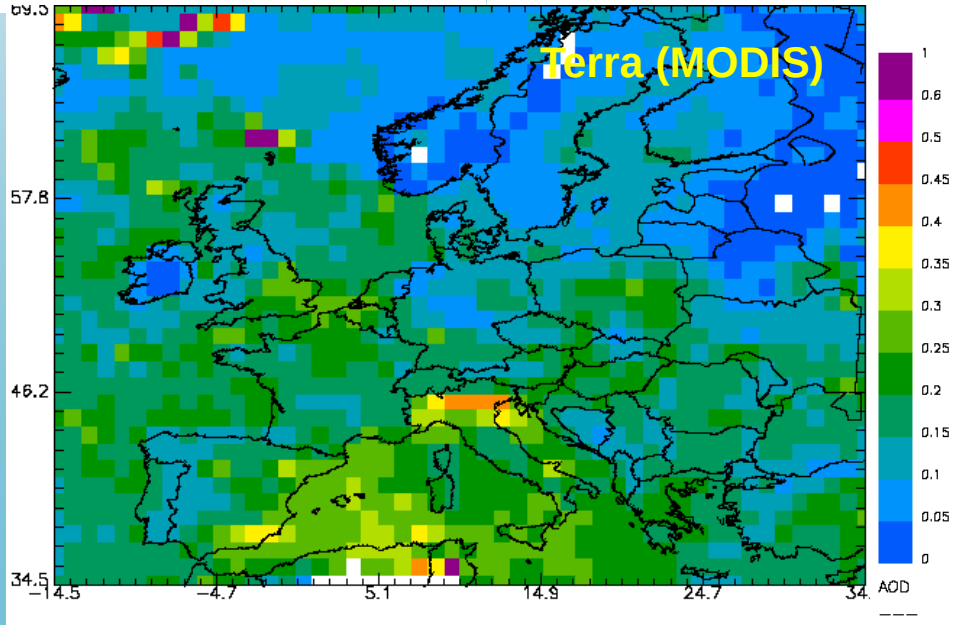
Monthly averages, June

FARM



FARM (MEGAN/Biog. Emiss.)





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MODIS data used in this study were produced with the Giovanni online data system, developed and maintained by the NASA GES DISC.

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- *EMEP Chemical Coordinating Centre at NILU for making available PM_{10} and ozone data;*

- *Michael Haller for making available MEGAPOLI models evaluation results.*

Thank you for your attention!