An evaluation of the UoWM MM5-SMOKE-CMAQ modelling system for Western Macedonia

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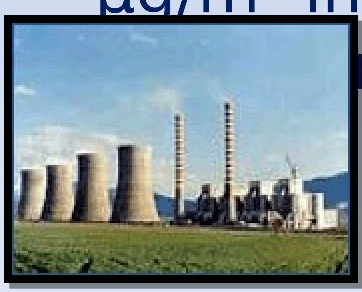
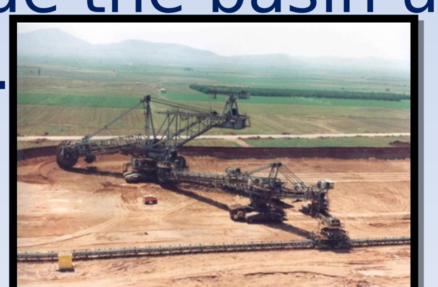
Industrial Activity in Western Macedonia

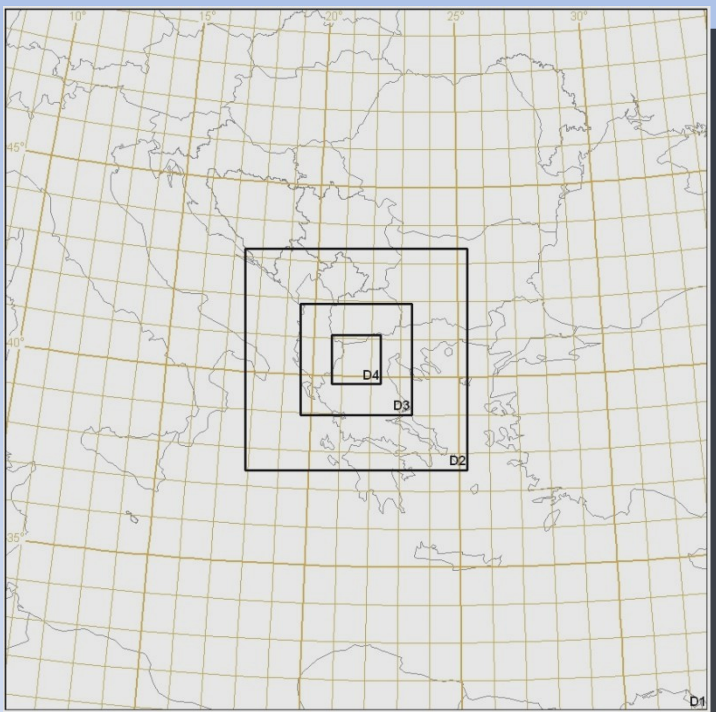
- The greater lignite basin of the region is the major power supplier for Greece and FYROM.
- 65% of the electrical energy needs in Greece and 70% of the FYROM are produced in the coal fired power plants of the region.
- More than 150,000 people live within the Greek part of the basin, with the main towns being Kozani and Ptolemaida.
- PM_{10} is the main air quality concern. PM_{10} exceedances are observed for the daily limit of 50 μg/m^3 inside the basin under certain meteorological ns.

The UoWM operational system

- Database with geographical and population data
- Detailed pollution sources registry and emissions inventory
- Depicting current conditions in real time via connection to a network of monitoring stations owned by the Greek Public Power Company, plus UoWM’s own meteo and air quality station
- 96-hour meteorological predictions using MM5
- Emissions processing using SMOKE
- 72-hour air quality predictions using CMAQ
- CMAQ forecasts include scenarios where emissions from power plants and/or lignite mines are turned

MM5 configuration



Two-way nested scheme using 4 domains:

30 vertical layers used

- D1: 38 × 38 cells 54 km resolution
- D2: 36 × 36 cells 18 km resolution
- D3: 54 × 54 cells 6 km resolution
- **D4: 72 × 72 cells 2 km resolution**

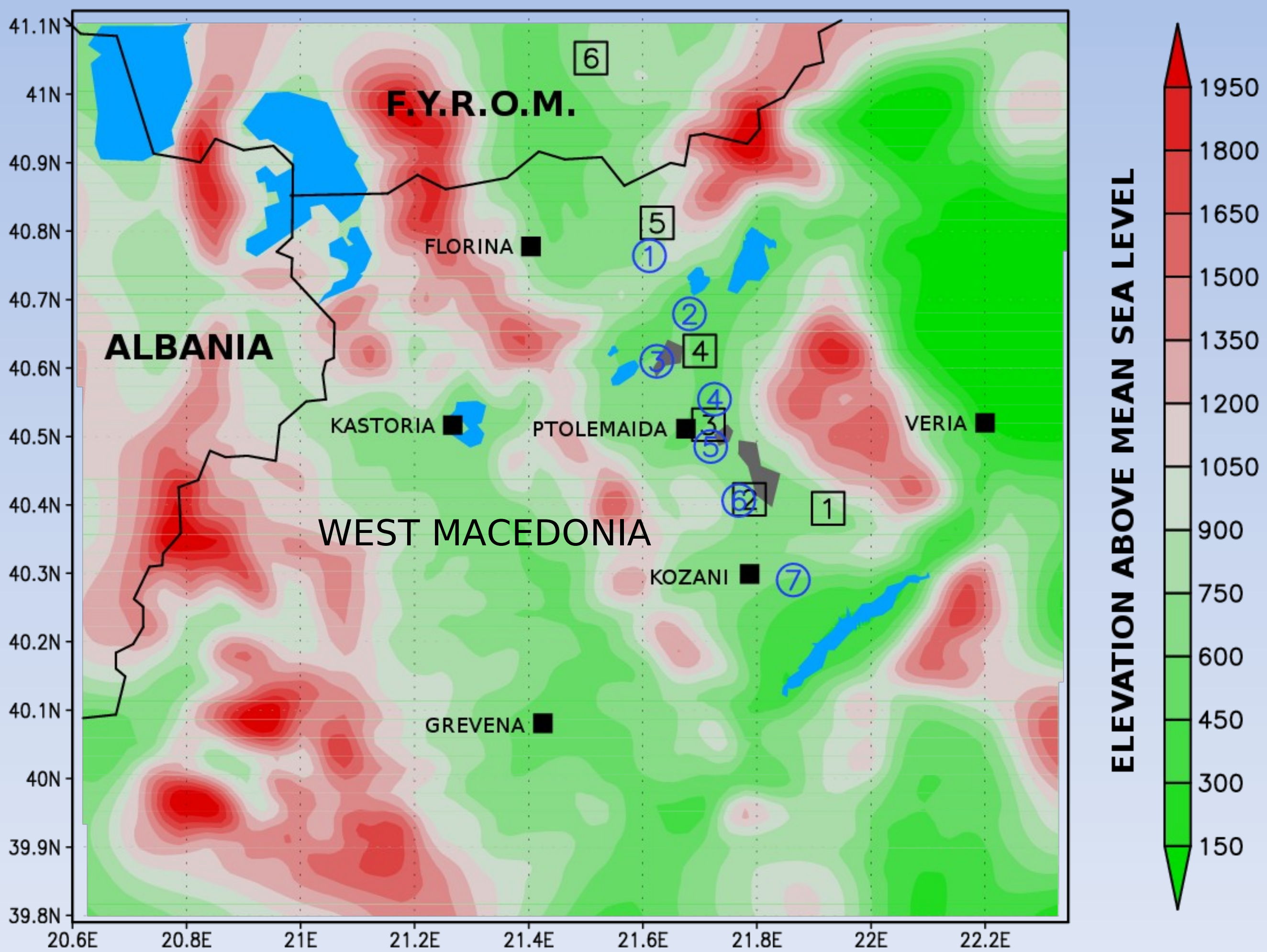
Physical parameterization:

- MRF PBL scheme
- Grell cumulus parameterization (except on finest domain D4)
- “Simple ice” moisture scheme
- RRTM radiation scheme

Initial / Boundary conditions:

- GFS model (from NCEP’s server, USA)

A detailed view of the region / computational domain D4



POWER PLANTS:

2.AG. DIMITRIOS (1595 MW)
3.KARDIA (1250 MW)
4.PTOLEMAIDA (620 MW)
5.AMYNTAIO (600 MW)
6.MELITI (330 MW)
7.REK BITOLA (675 MW)

MONITORING STATIONS:

10.VEVI
11.AMYNTAIO
12.ANARGYROI
13.PENTAVRYSOS
14.PPC VILLAGE
15.PONTOKOMI
16.PETRANA
\+ University (KOZANI)

Lignite mines shown in grey

Emissions inventory

CO, NH_3, NO_x, PM_{10}, $PM_{2.5}$, SO_2, VOC emissions on a 2 × 2 km grid

Sources included

- Power plants
- Lignite mines
- Traffic network
- Domestic heating
- Industry
- Biogenic emissions

Emissions processing performed using SMOKE

Sparse Matrix Operator Kernel Emissions v.2.4, UNC, USA

Current simplifications

- No fugitive dust included except for lignite mines.
- Lignite mines emissions also assumed fixed, independent of the meteorological conditions (wind, rain etc).

CMAQ configuration

- Only finest domain used (D4), 70 × 70 cells, 2 × 2 km, 30 layers
- CB-IV chemical mechanism
- Aero3 aerosol module
- Custom profile boundary conditions with PM_{10} of 20 µg/m^3 at the bottom layers, decreasing to zero at the upper layers

Categorization into weather categories

- Weather was categorized into 11 different categories according to a clustering algorithm (Sfetsos *et al* 2005)

- The categories were derived using GFS model data for the entire summer periods (April – September) of 2006 – 2007 (NCEP FNL Global Tropospheric Analyses datasets)

- For each day, its category is derived considering GFS variables at 00:00, 12:00 and 24:00 at the pair of GFS cells which cover the Kozani-Ptolemaida basin:

  - u, v wind components at 10 m AGL
  - u, v wind components at 500 hPa
  - Temperature at 2 m AGL
  - Relative humidity at 2 m AGL
  - Mixing layer height

MM5 validation for selected days

- A simulation was performed for a representative date of each category
- For each date the simulation was started one day in advance to reduce the influence of initial conditions
- Validation is against the measurements of 10 monitoring stations along the lignite basin

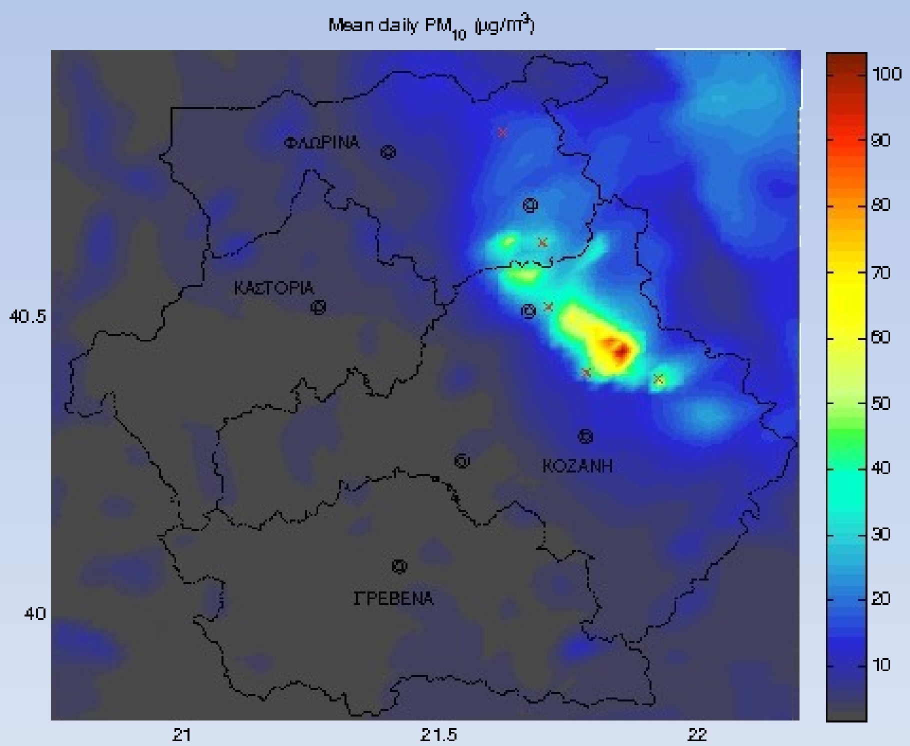
Category	Date	Wind Speed (ms^{-1}) at 10 m AGL				Wind Direction (deg) at 10 m AGL			
		m_o	m_p	mean bias	RMSE	m_o	m_p	mean bias	RMSE
1	**28-07-2007**	*2.06*	*1.85*	*0.21*	*1.35*	*85.4*	*91.8*	*-6.4*	*64.5*
2	**04-05-2007**	*1.88*	*2.39*	*-0.52*	*1.68*	*123.7*	*103.3*	*20.4*	*76.4*
3	**29-05-2007**	*3.29*	*4.79*	*-1.51*	*3.04*	*233.1*	*253.9*	*-20.8*	*71.9*
4	**15-09-2007**	*3.13*	*3.24*	*-0.11*	*2.15*	*335.2*	*333.9*	*1.3*	*70.8*
5	**22-05-2007**	*2.71*	*3.53*	*-0.82*	*2.44*	*334.2*	*345.5*	*-11.3*	*80.6*
6	**21-09-2007**	*3.83*	*2.66*	*1.18*	*2.49*	*337.7*	*337.5*	*0.2*	*58.4*
7	**17-05-2007**	*2.67*	*2.78*	*-0.11*	*1.73*	*240.8*	*272.6*	*-31.8*	*72.4*
9	**13-05-2007**	*2.17*	*2.20*	*-0.03*	*1.75*	*73.1*	*32.7*	*40.4*	*84.9*
10	**26-06-2007**	*2.98*	*3.30*	*-0.32*	*1.95*	*261.7*	*266.6*	*-4.9*	*61.5*
11	**12-04-2007**	*2.07*	*3.12*	*-1.05*	*1.71*	*321.3*	*342.2*	*-20.9*	*89.23*

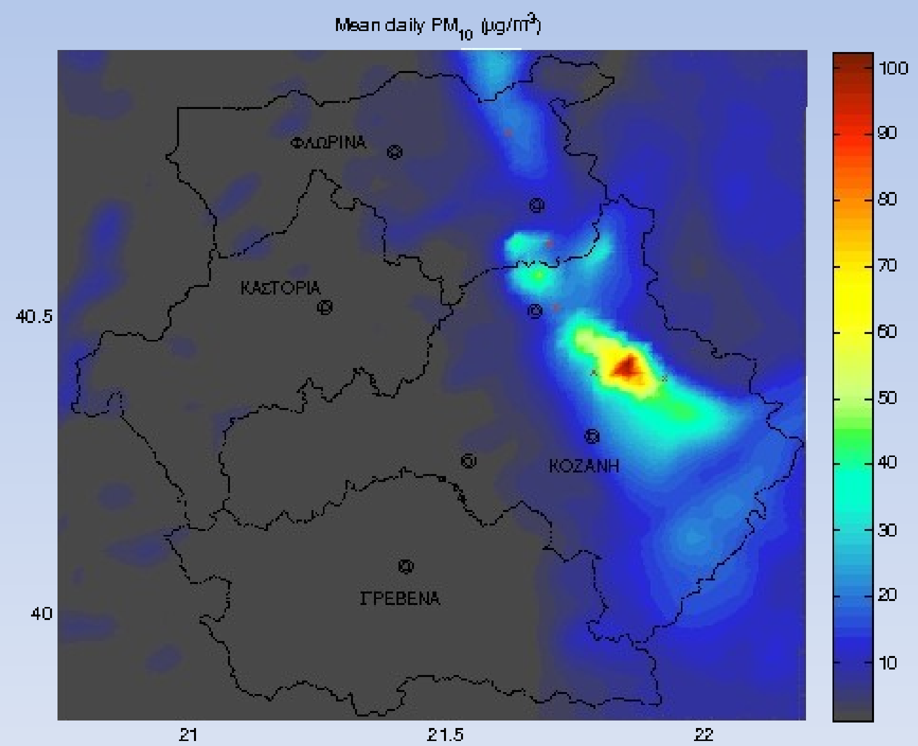
m_o: mean of observations, m_p: mean of predictions

Mean predicted PM_{10} for sample dates

Day 2 (04/05/2007): Weak surface winds. Strong W winds at the previous night.

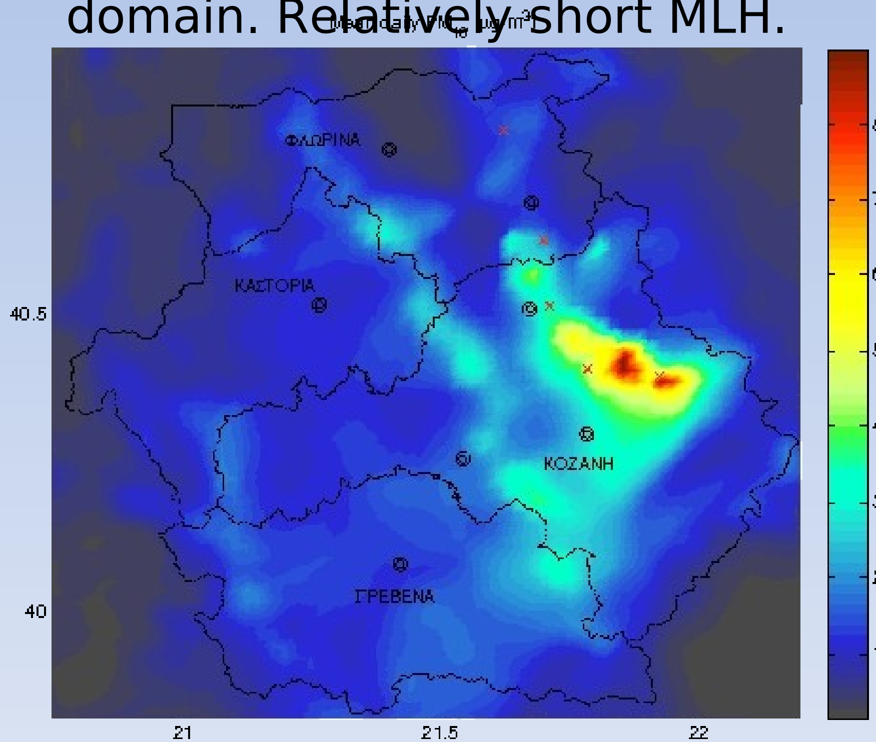
Day 4 (15/09/2007): NW winds, weak in the morning, strong in the afternoon and evening.



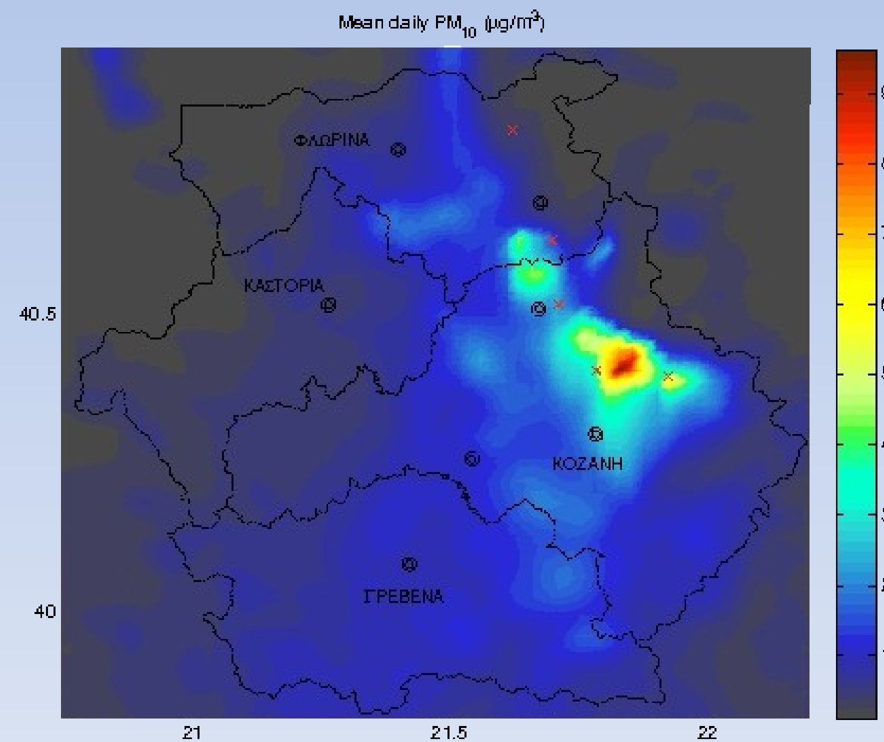


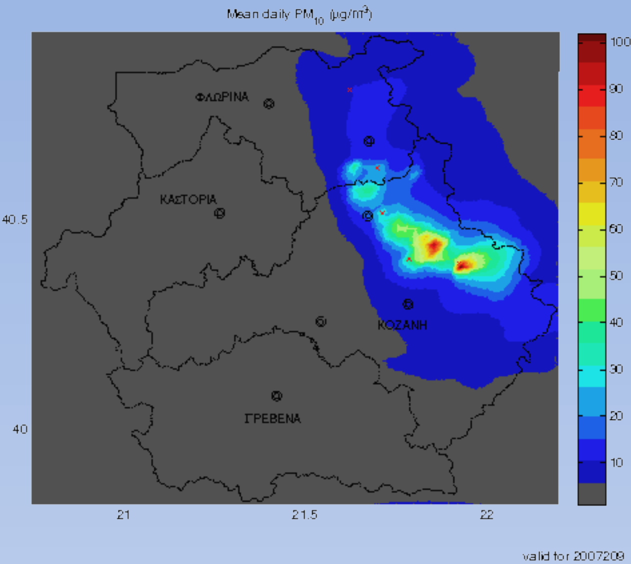
Mean predicted PM_{10} for sample dates

Day 6 (21/09/2007): Strong N-NW winds within the basin, weak winds elsewhere. In the afternoon weak SE winds appear at the south part of the domain. Relatively short MLH.

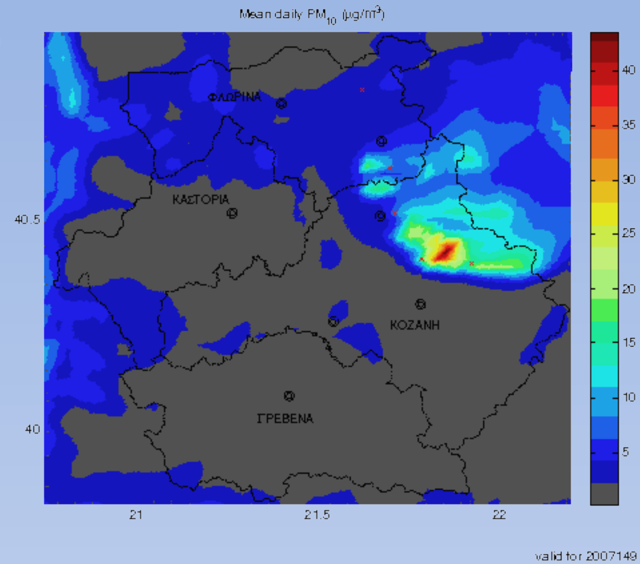


Day 11 (12/04/2007): Strong N winds in the morning, weaken significantly in the evening. Relatively short MLH.

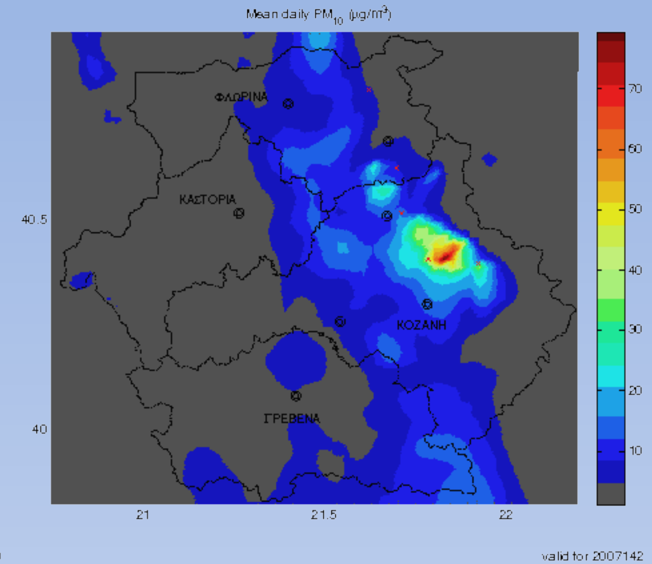




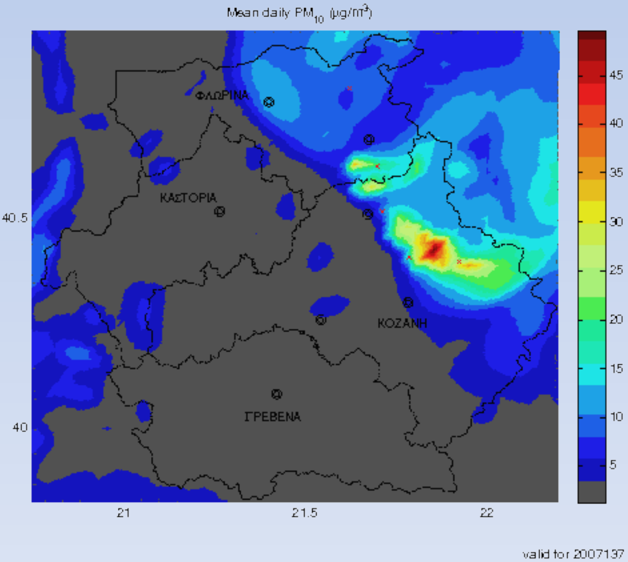
Day 1 (28 – 07 – 2007)



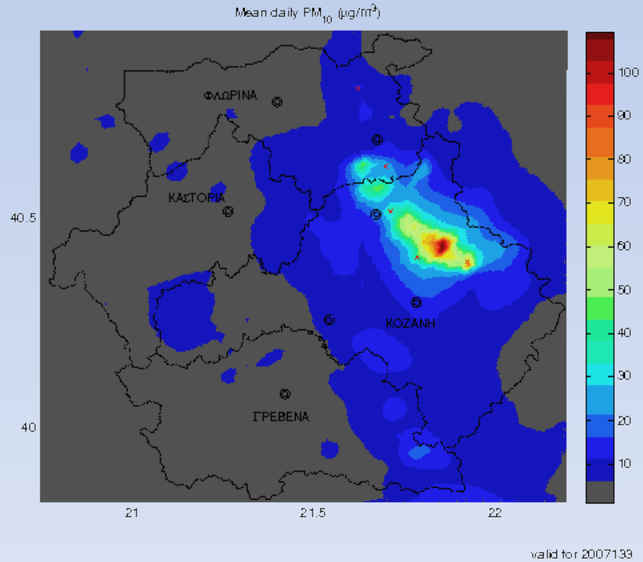
Day 3 (29 – 05 – 2007)



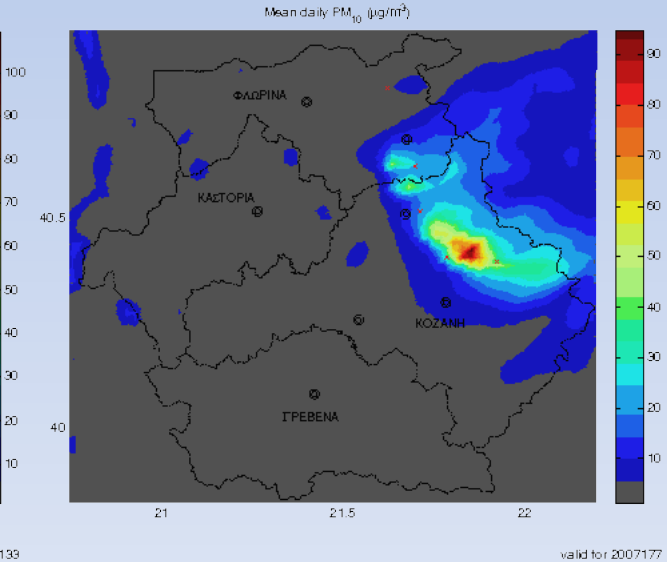
Day 5 (22 – 05 – 2007)



Day 7 (17 – 05 – 2007)



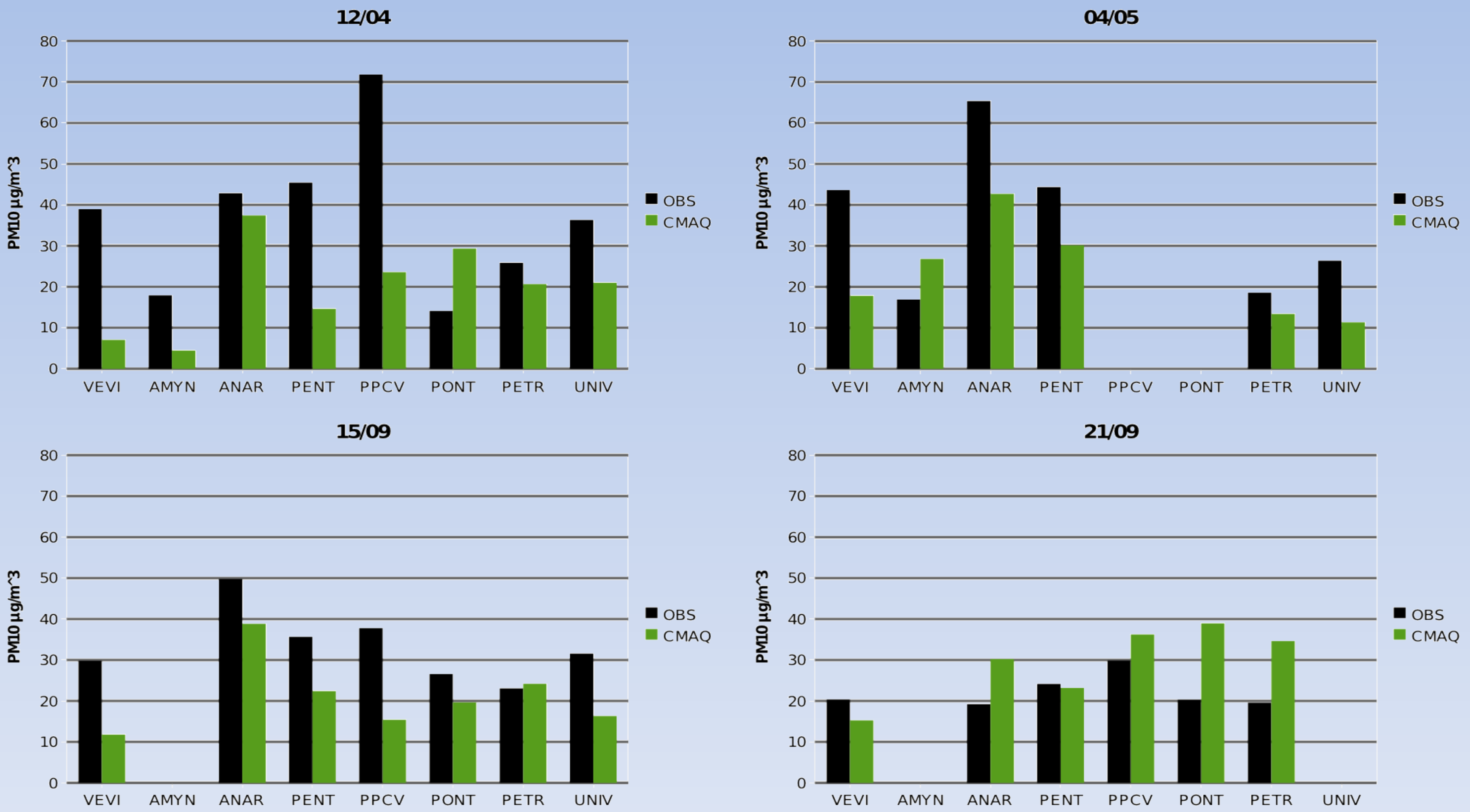
Day 9 (13 – 05 – 2007)



Day 10 (26 – 06 – 2007)

Comparison against observations

mean observed and predicted PM_{10} concentrations at each site



Comparison against observations

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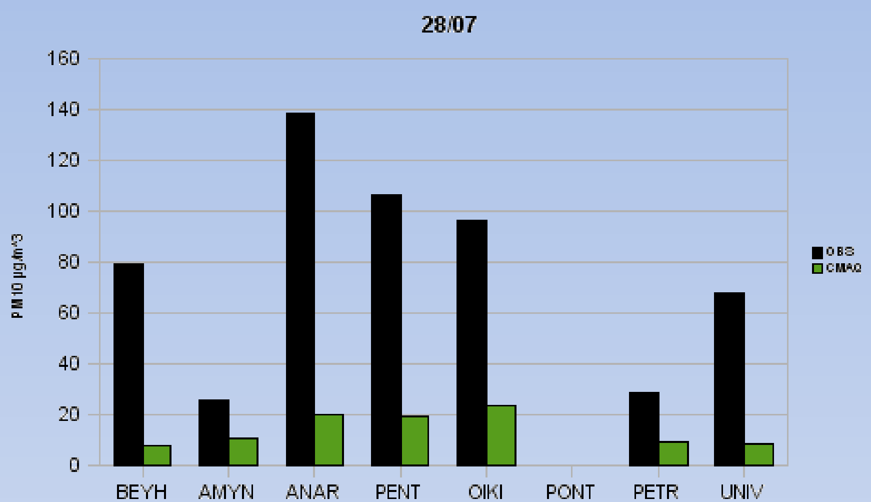
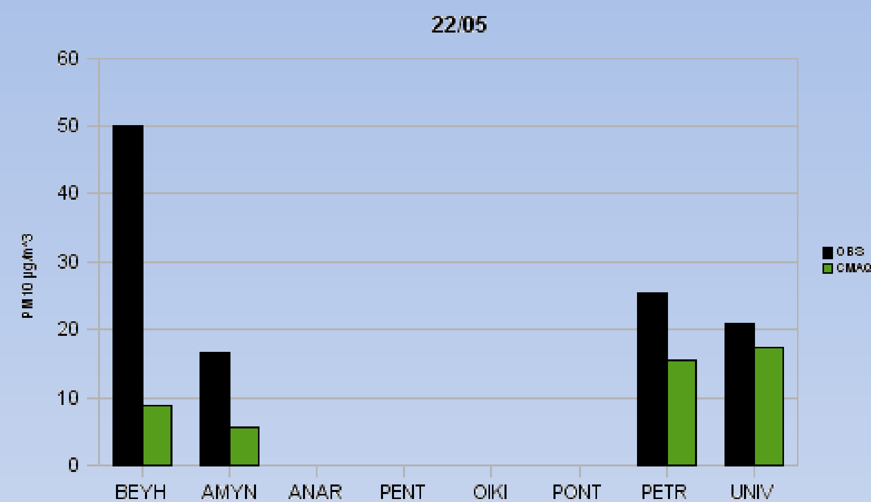
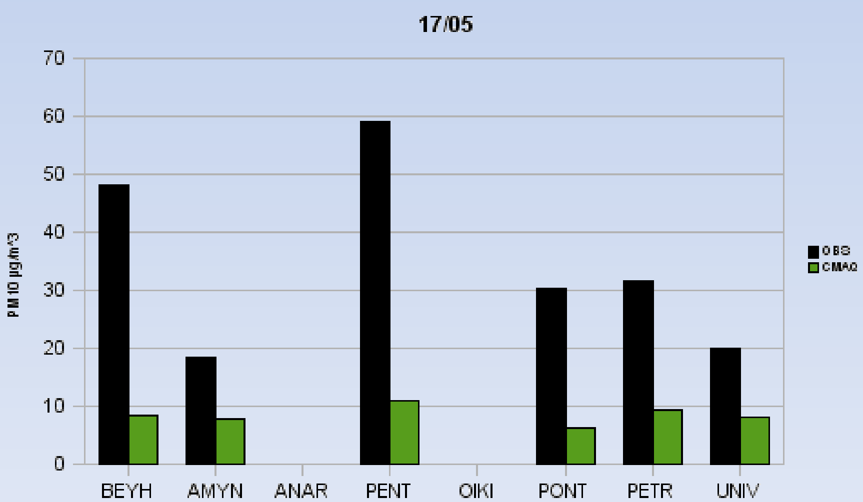
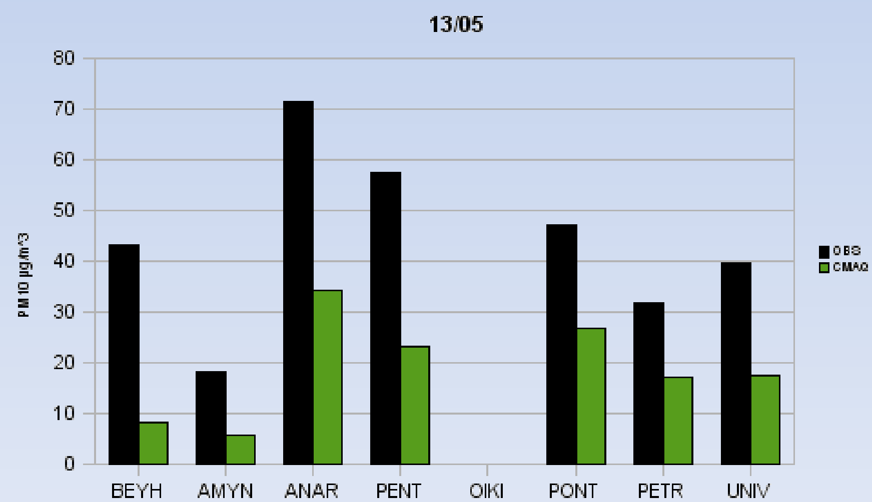


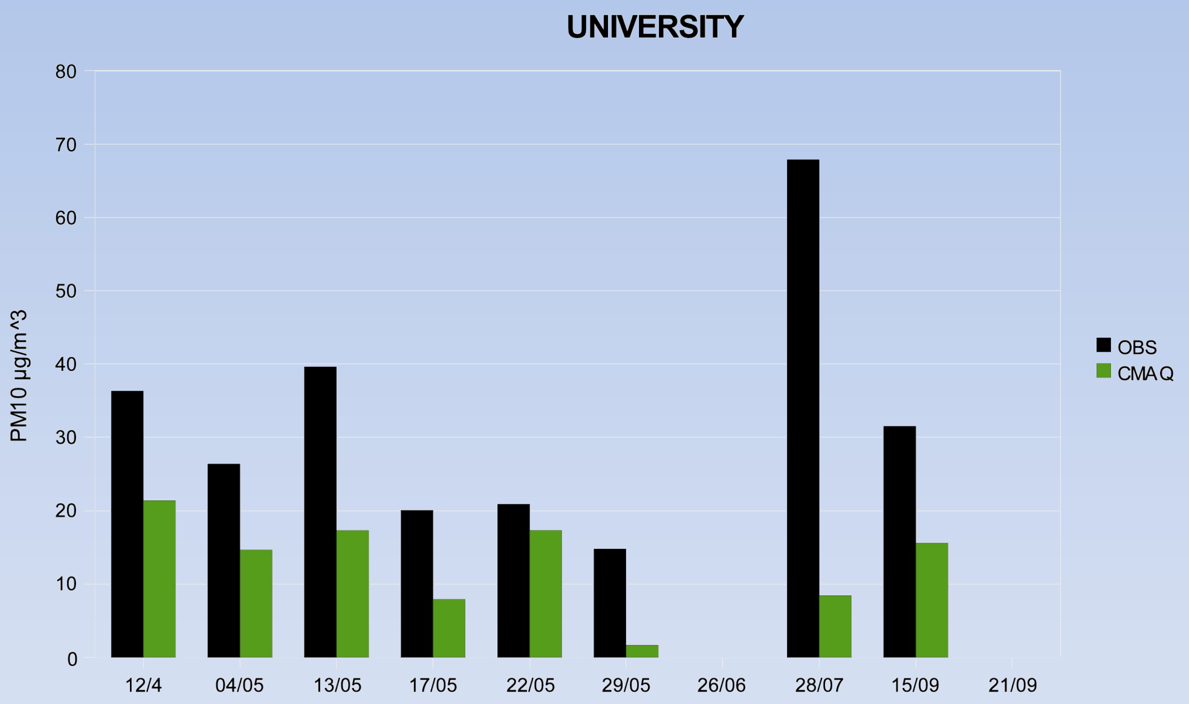






Comparison against observations

mean observed and predicted PM_{10} concentrations at the UoWM station, for all dates



Concluding remarks

- The emissions inventory needs some refinement. Observations suggest that there may be a strong source of PM in the north, which is not adequately included in our emissions inventory.
- Apart from the power plants, the lignite mines also play a major role in PM concentration and it must be ensured that their emissions are accurately modeled.
- Boundary / initial conditions derived from larger scale models are expected to improve the results.
- Categorization into weather types via a clustering algorithm offers the important advantage that each day can be classified automatically.
- To assess the usefulness of this weather categorization, more simulations must be performed over several days of each weather category, to identify common air quality trends among days of the same category.

Thank you for your attention