The Coupled Chemistry Meteorology Model BOLCHEM: an application to the air pollutants level in the Po Valley (Italy) hot spot.

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motivation

- strong relationship between air quality and meteorology;
- development of numerical models that couple meteorological, dynamical and chemical atmospheric processes;

- the Po Valley is one of the most polluted areas in Europe;
- several emission sources: industrial activities, road transport, agricultural activities, livestock farming
- transboundary contribution to the pollutants concentration levels
- the topography of the Valley causes air stagnation with consequent low pollutant dispersion
- existing model inter-comparison exercises in the Po Valley

The model BOLCHEM

Coupled Chemistry Meteorology Model

- **meteorology and chemistry variables are simultaneously treated using the same physics (e.g. same vertical diffusion scheme)**

- **same grid: horizontal and vertical components**
- **same time step**

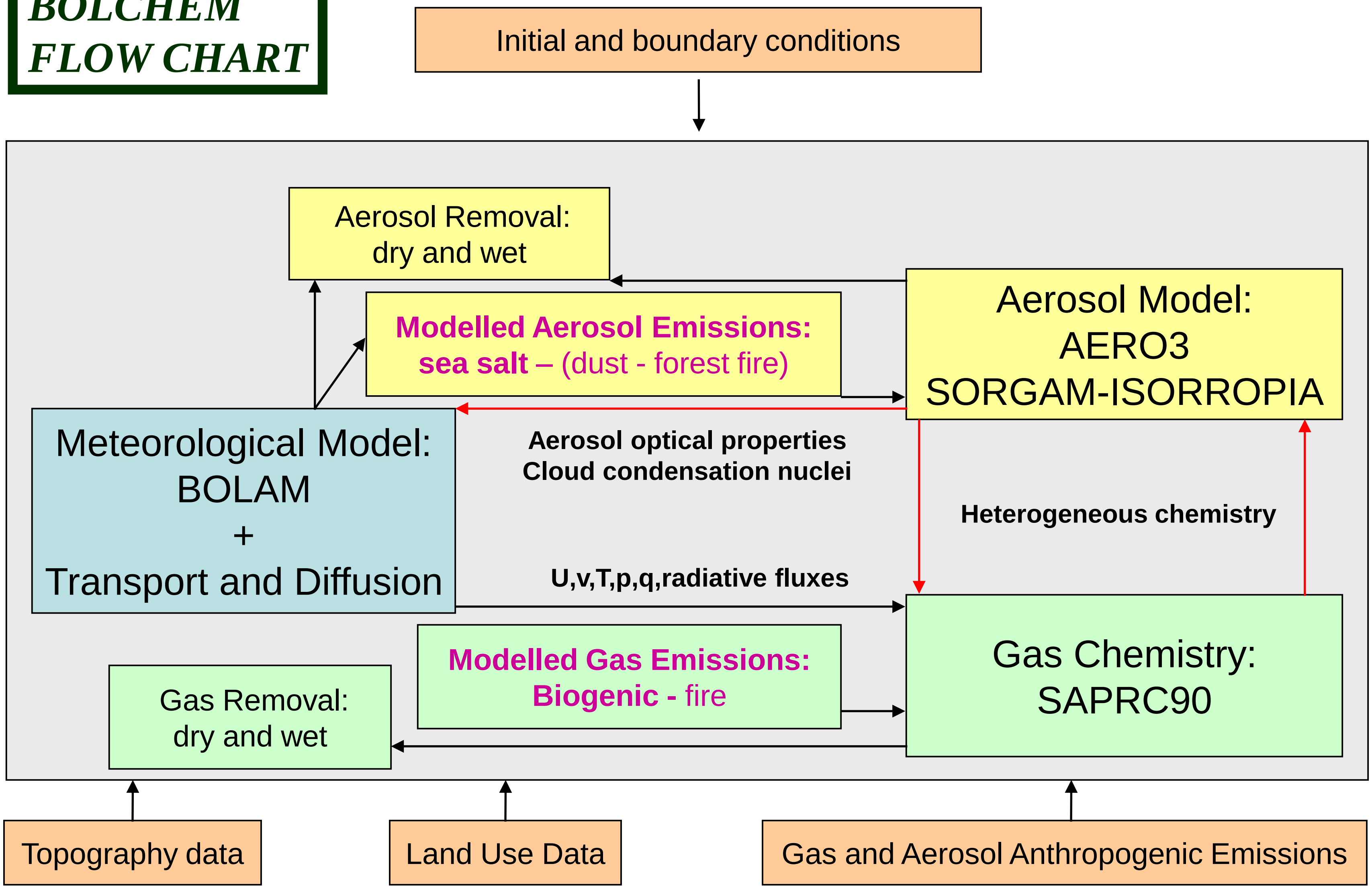
- **feedback possible (not implemented)**

The model BOLCHEM

- **Meteorological component: BOLAM (hydrostatic)**
- **Photochemistry scheme: SAPRAC90**

  (lumped-molecular condensed mechanism) extended to describe the formation of condensable organic products
- **Aerosol module:**
  - **AERO3 model**
    modal approach
    ***Aitken mode* (0.01 -0.1 µm)**
    ***Accumulation mode* (0.1-2.5 µm)**
    ***Coarse mode* (2.5-10 µm)**
  - **SIA: equilibrium model ISORROPIA**
    (ammonia-sulfate-nitrate-water-system)
  - **SOA: Gas/particle partitioning SORGAM**
- **Dry deposition (resistance model)**
- **Wet deposition (EMEP scheme, using simulated precipitation at every vertical level)**

BOLCHEM FLOW CHART



model set up

simulation period: **December 2009 - February 2010 (winter period)**
June 2010 - August 2010 (summer period)

simulation domain: 2 nested grid **(15°W to 35°E, 30°N to 60°N)**
(6°E to 20°E, 36°N to 48°N)

spatial resolution: **dx = dy = 0.4° (parent domain)**
dx = dy = 0.1° (child domain)

the vertical resolution: **50 levels for meteorology, 25 for chemistry. The lower layer is approximately 20m thick above the surface**

time step: 360 s (parent simulation) - 90 s (child simulation)

boundary and initial conditions for meteorology: **are supplied by ECMWF. The lateral boundary conditions are updated every 6 hours. The weather fields are re-initialized every 24 hours with the analyses in order to avoid an excessive error growth in the meteorological forecast.**

model set up

emissions, initial and boundary chemical conditions:

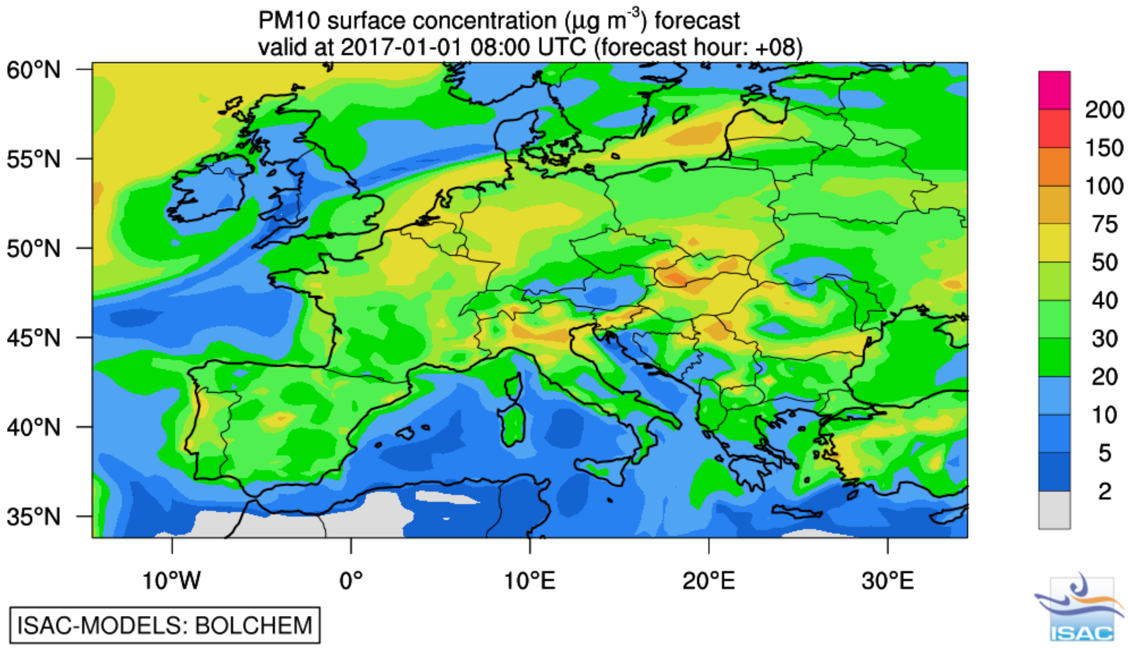
The chemical fields are driven by hourly surface emissions.

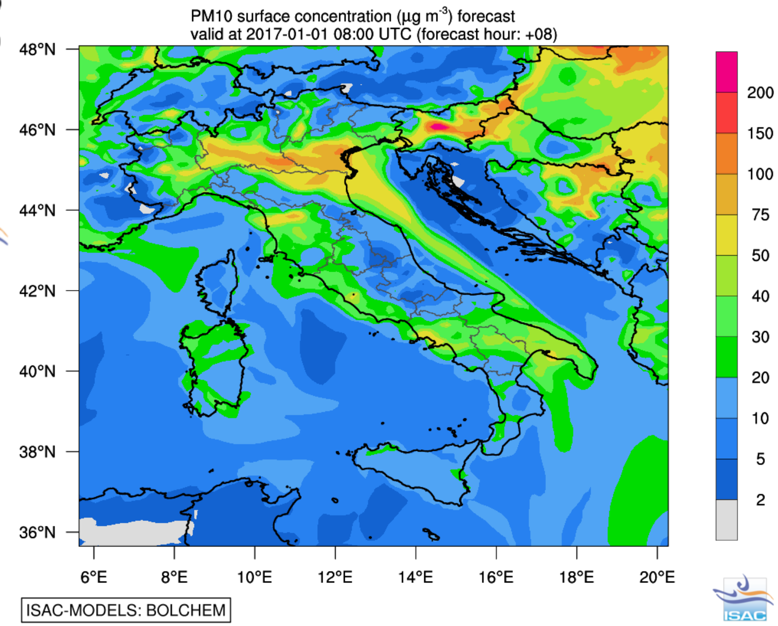
Antropogenic emissions: data set TNO 2010

Biogenic emission: based on potential emissions generated by NKUA (GEMS project) and calculated run time by the model

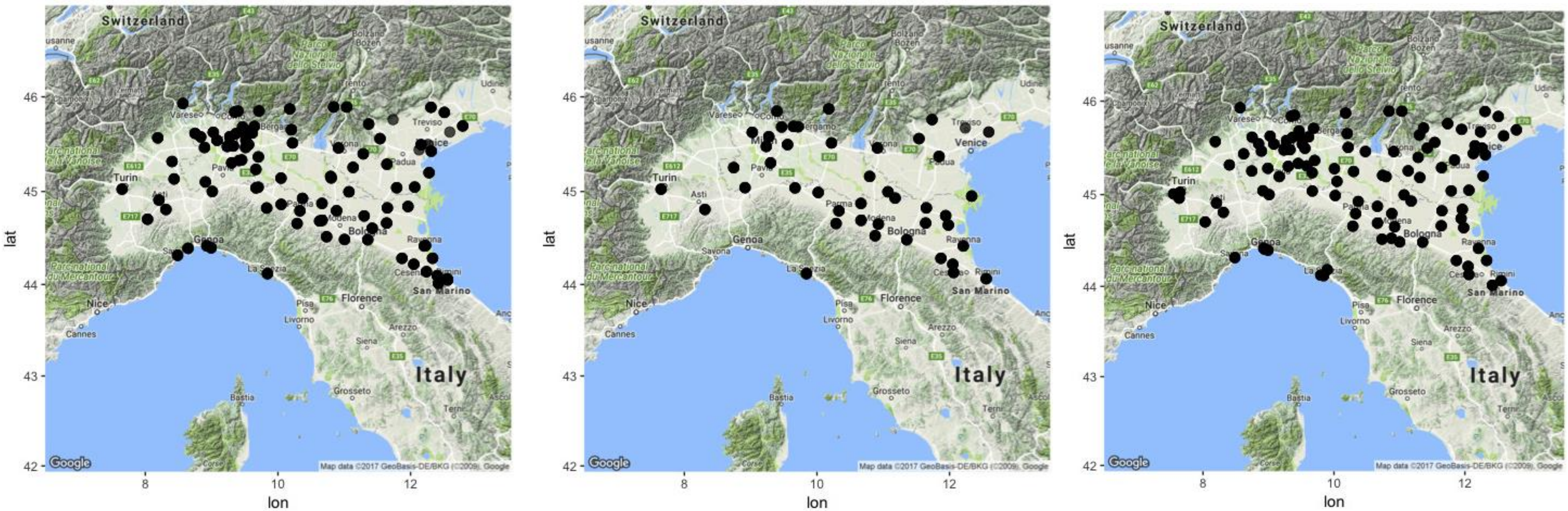
Initial and boundary conditions: monthly climatological fields INERIS (parent simulation), hourly fields from parent simulation (child simulation).

simulation domain





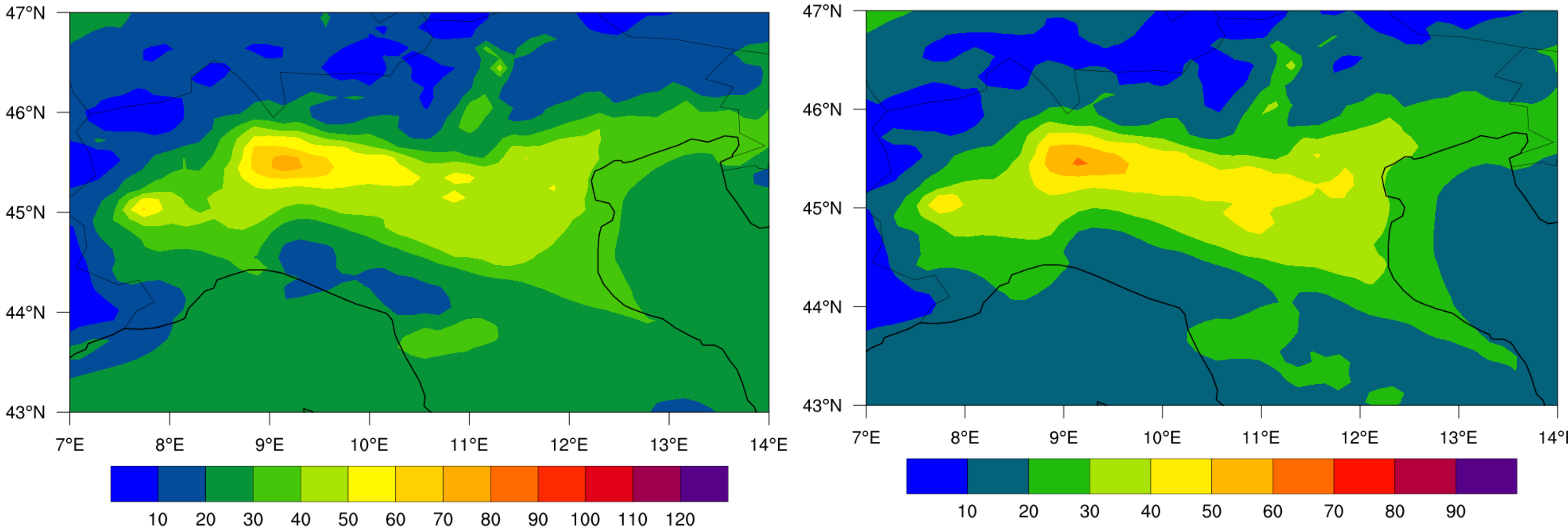
airbase stations



a) b) c)

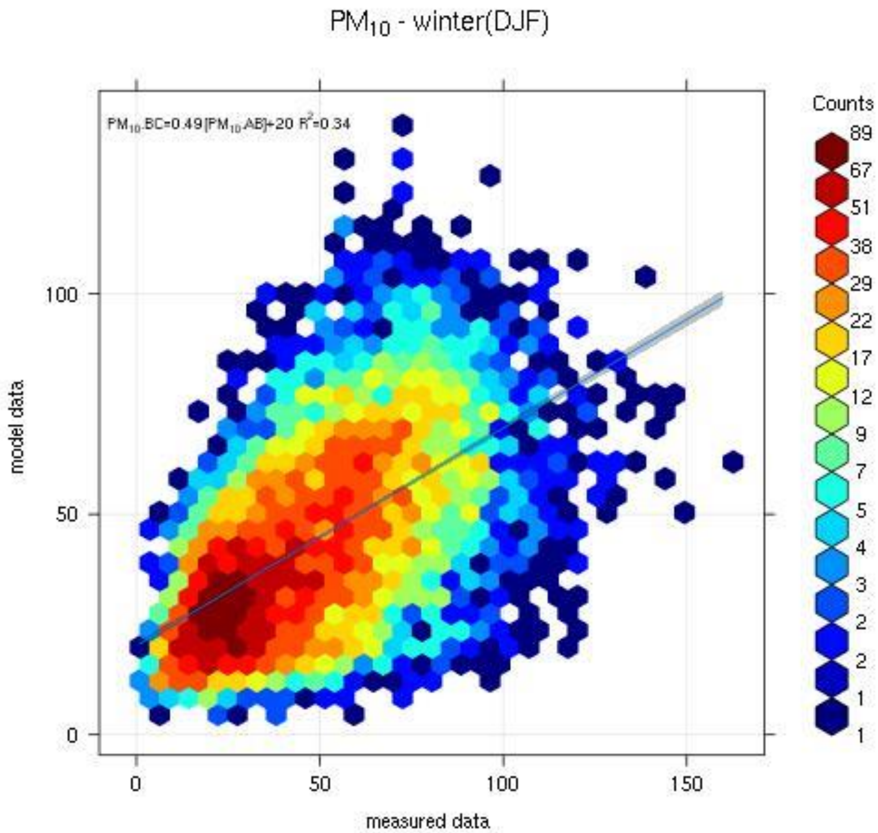
Airbase Stations (background) over the study domain for PM_{10} (a), $PM_{2.5}$ (b) and O_3 (c)

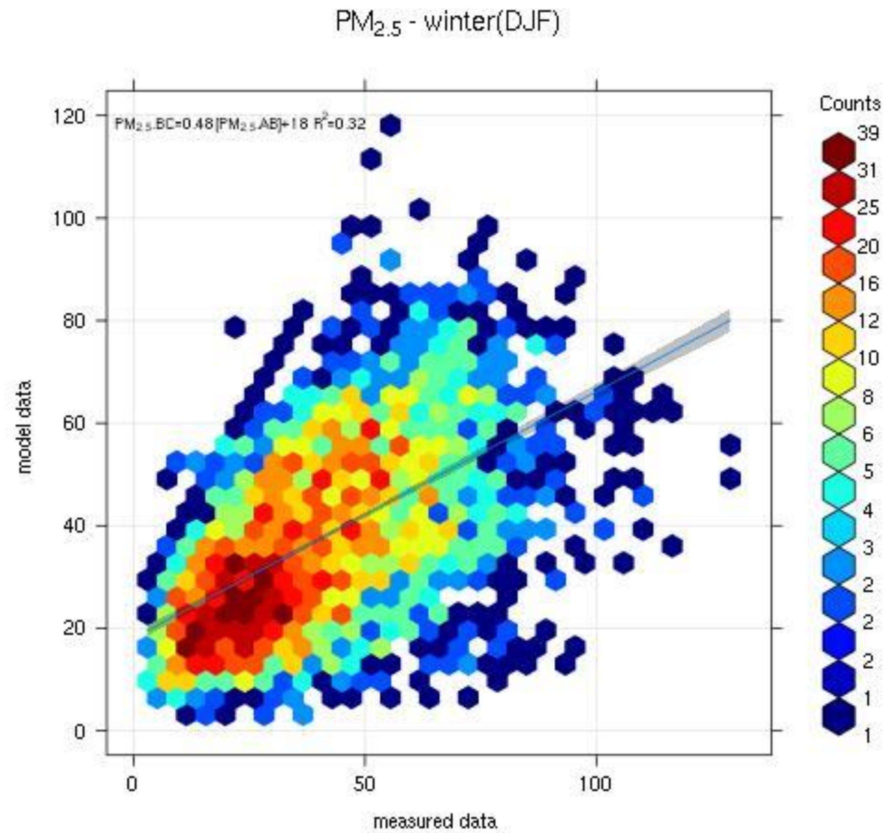
simulated ground concentration winter period



Simulated season averaged ground concentration over the study domain for PM_{10} (left) and $PM_{2.5}$ (right). Units are μg m^{-3}.

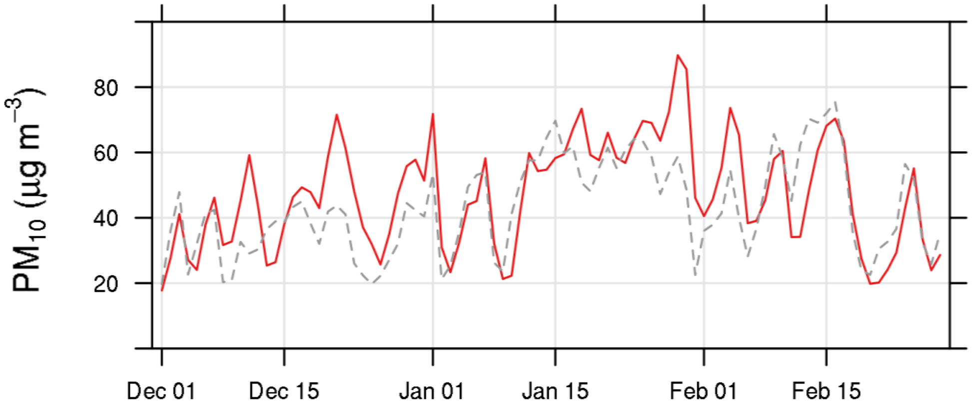
simulation results – winter period

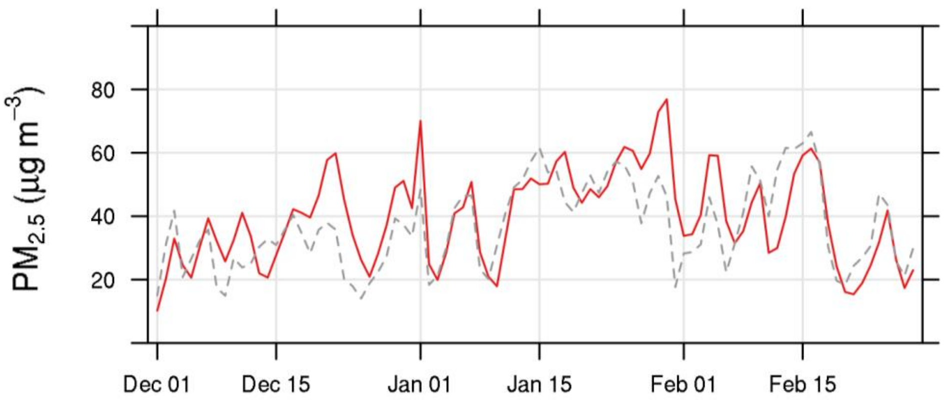




Modeled daily averaged concentration vs the observed one for PM_{10} (left) and $PM_{2.5}$ (right) at AirBase background stations (scatter plot). Units are $\mu g\ m^{-3}$.

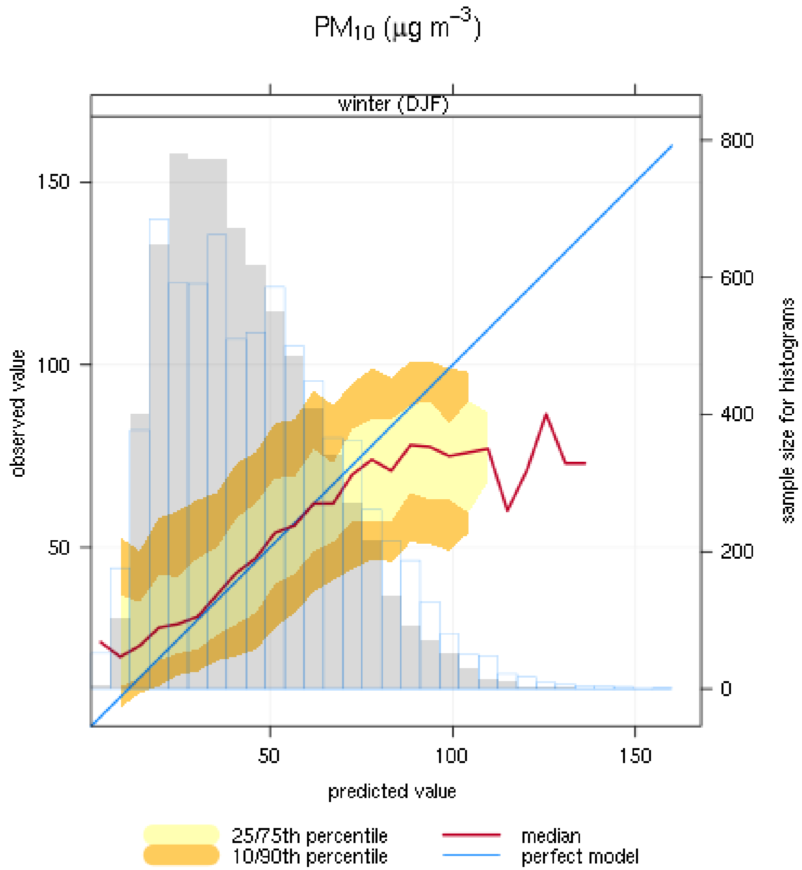
simulation results – winter period

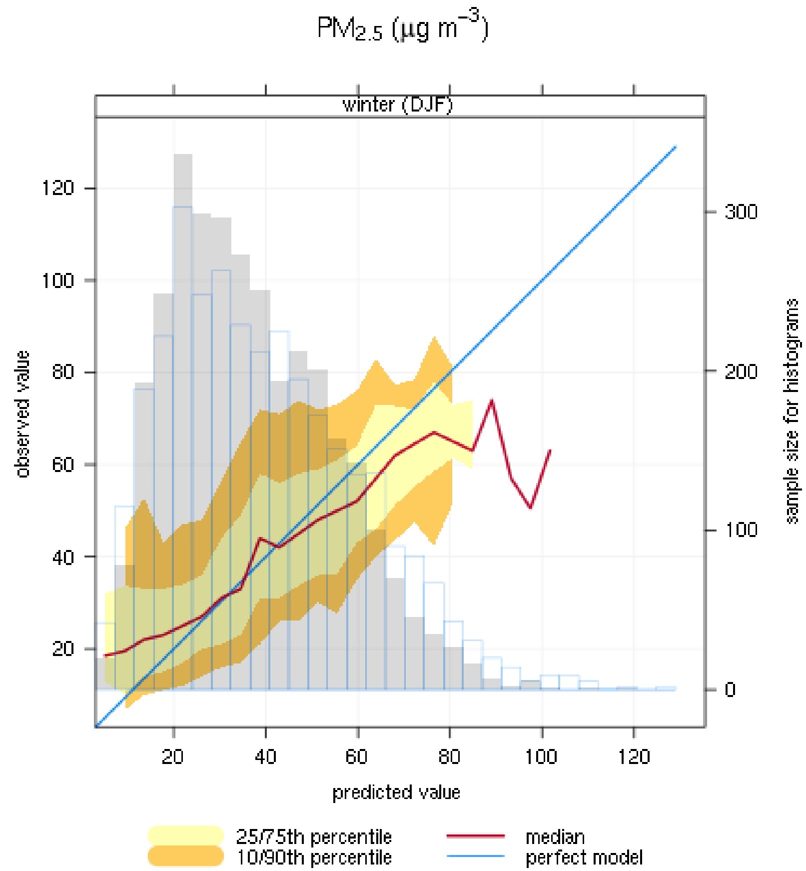




Time serie of modeled daily averaged concentration (dotted line) and the observed one (red line) for PM_{10} (top) and $PM_{2.5}$ (bottom) at AirBase background stations.

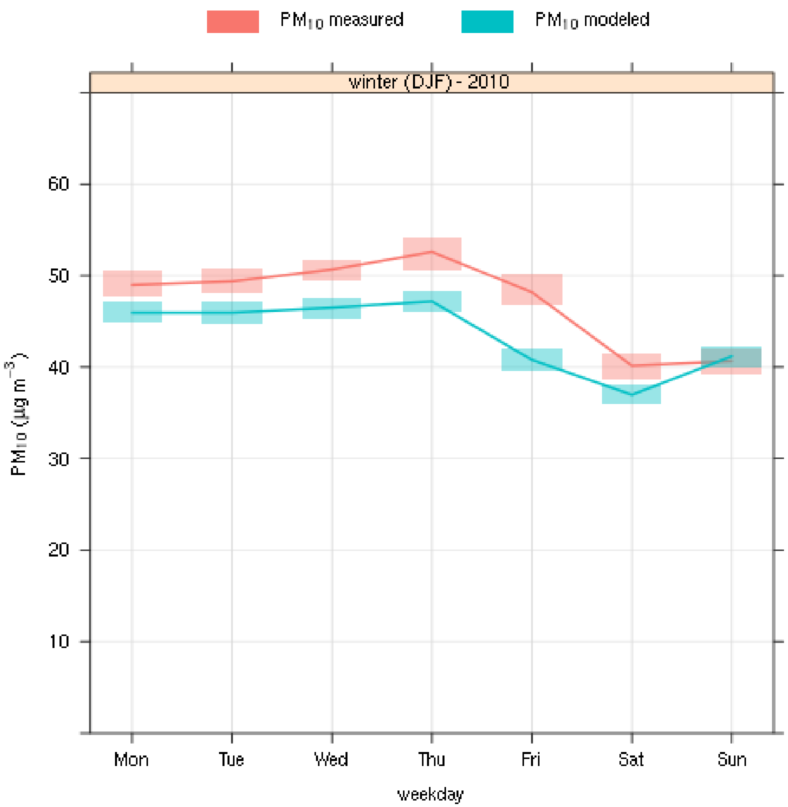
simulation results – winter period

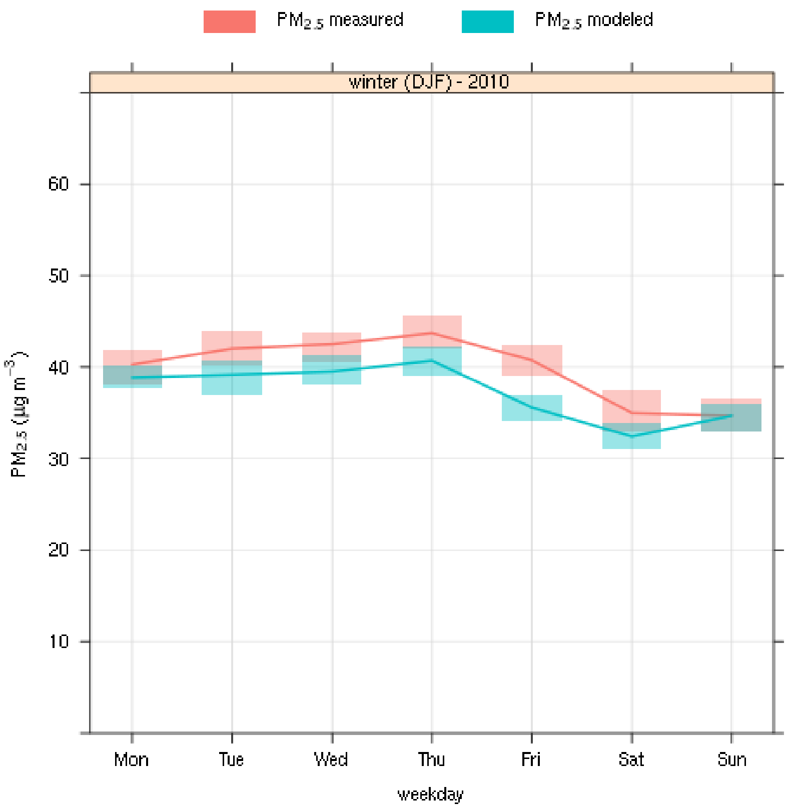




Conditional quantile (season) of daily averaged concentration for PM_{10} (left) and $PM_{2.5}$ (right) at AirBase background stations.

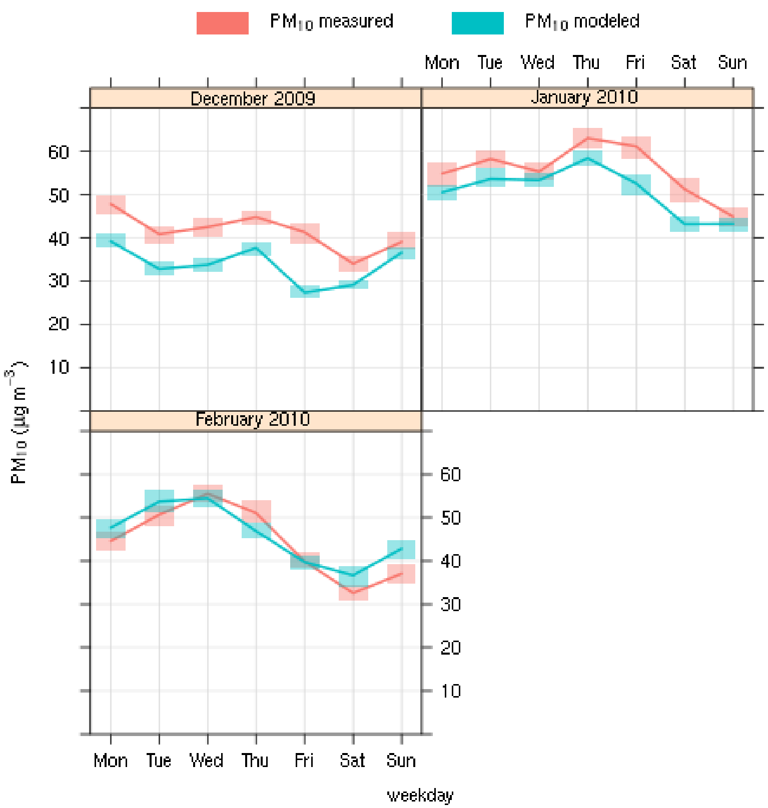
simulation results – winter period

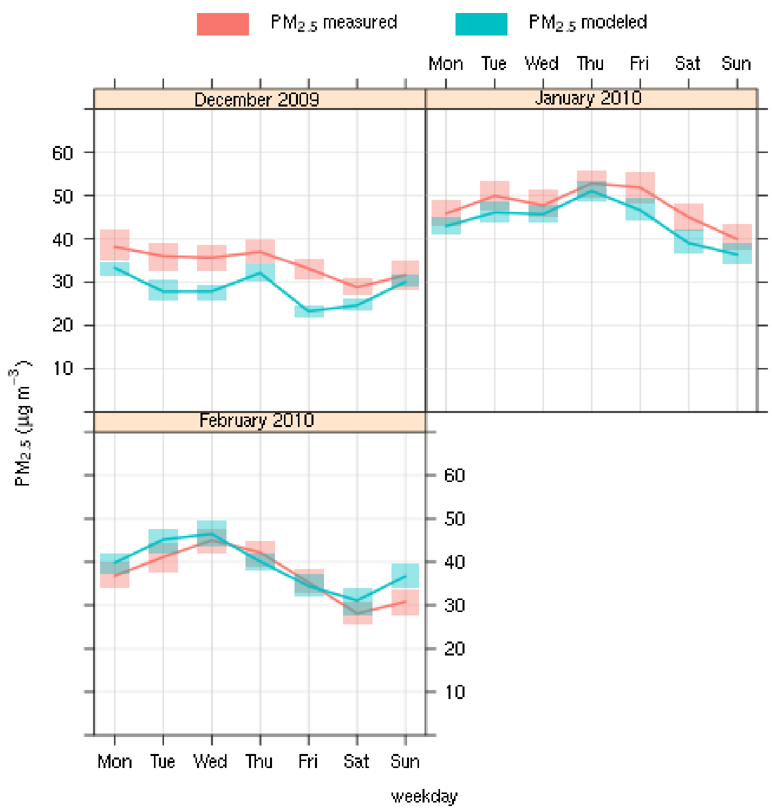




Weekday (season) averaged modeled concentration and the observed one of PM_{10} (left) and $PM_{2.5}$ (right) at AirBase background stations.

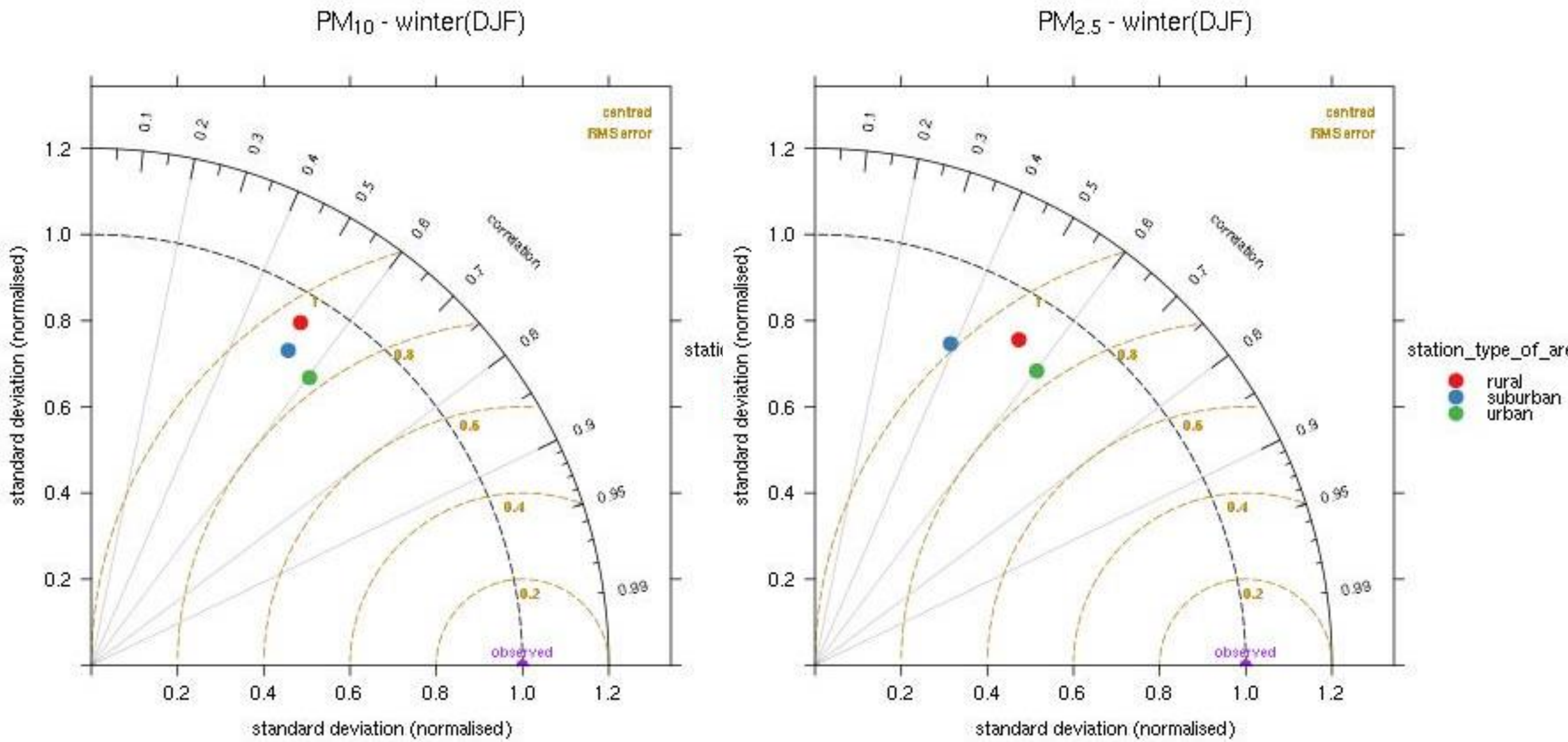
simulation results – winter period





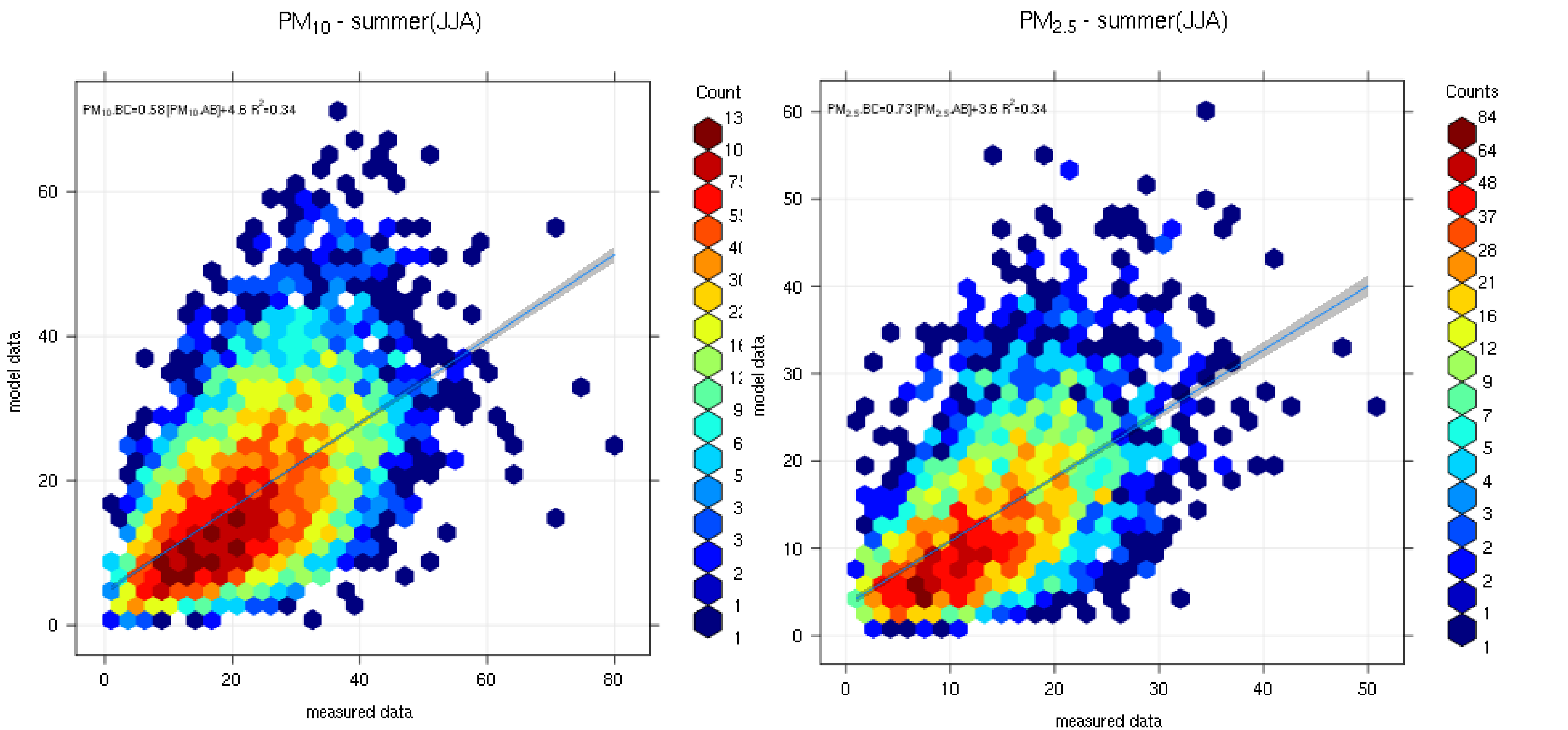
Weekday (month) averaged modeled concentration and the observed one of PM_{10} (left) and $PM_{2.5}$ (right) at AirBase background.

simulation results – winter period



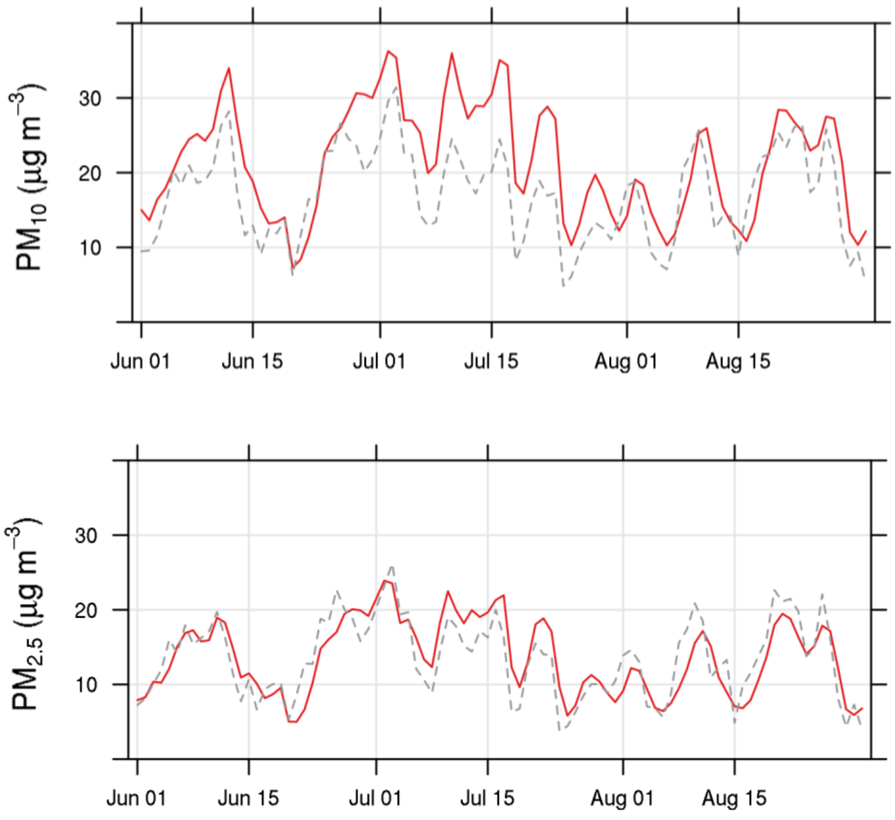
Taylor diagram for daily averaged PM_{10} (left) and $PM_{2.5}$ (right) ground concentration for the winter season.

simulation results – summer period



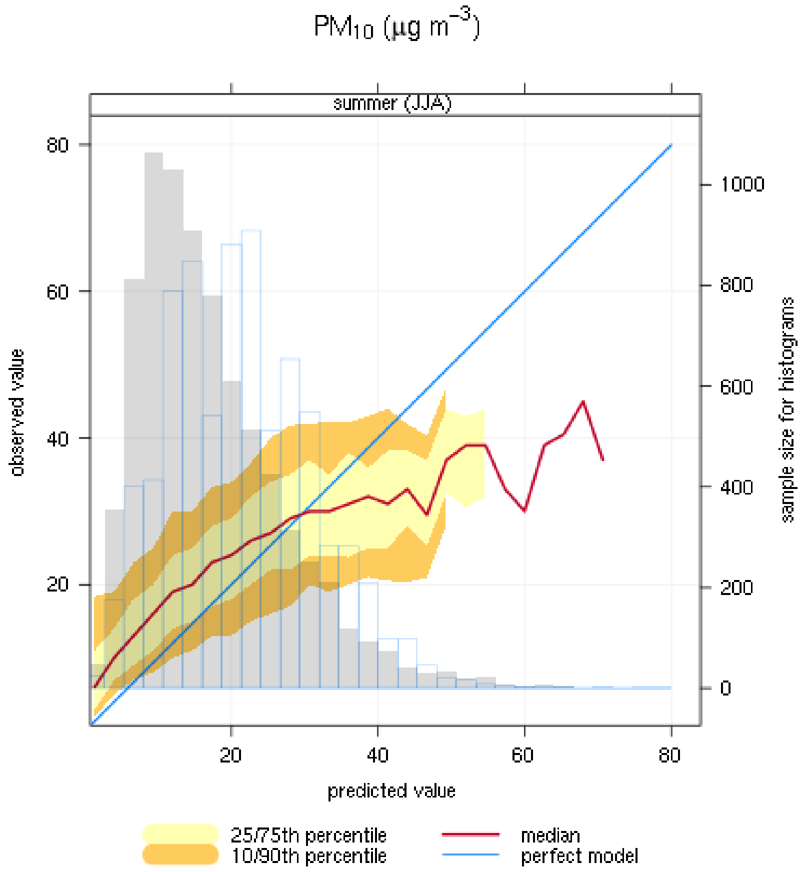
Modeled daily averaged concentration vs the observed one for PM_{10} (left) and $PM_{2.5}$ (right) at AirBase background stations (scatter plot). Units are $\mu g\ m^{-3}$.

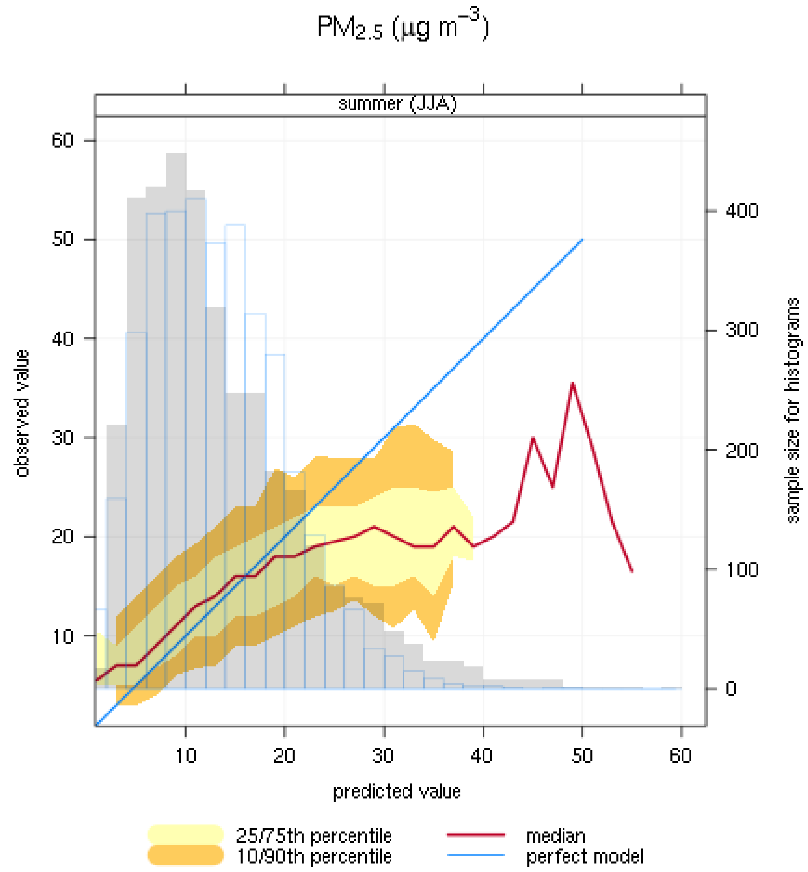
simulation results – summer period



Time serie of modeled daily averaged concentration (dotted line) vs the observed one (red line) for PM_{10} (top) and PM $_{2.5}$ (bootom) at AirBase background stations

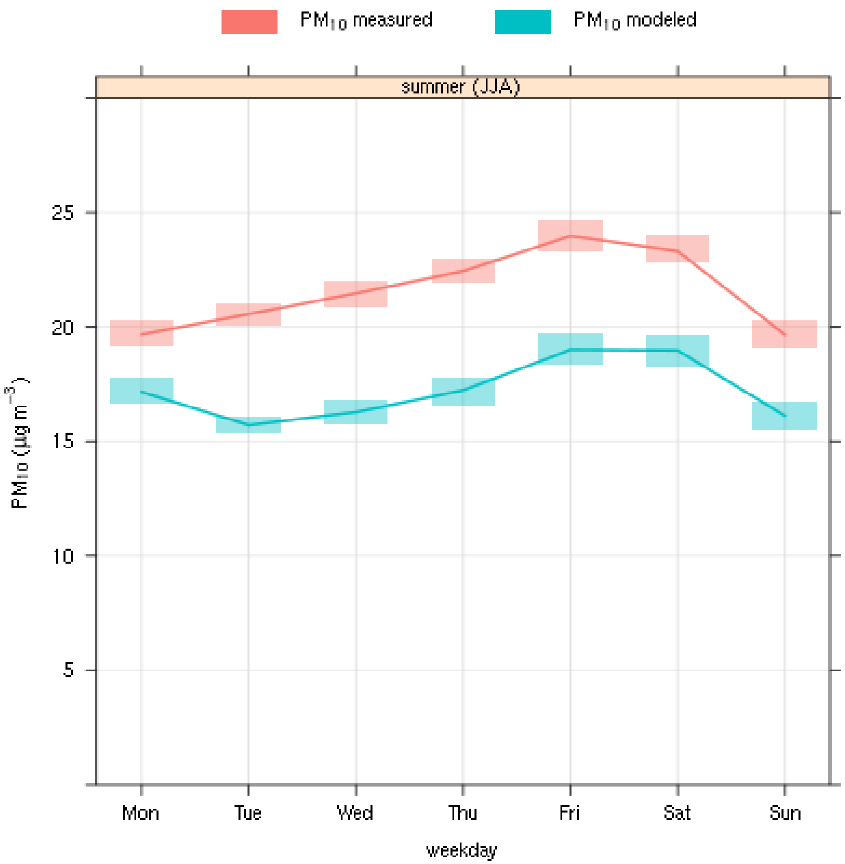
simulation results – summer period

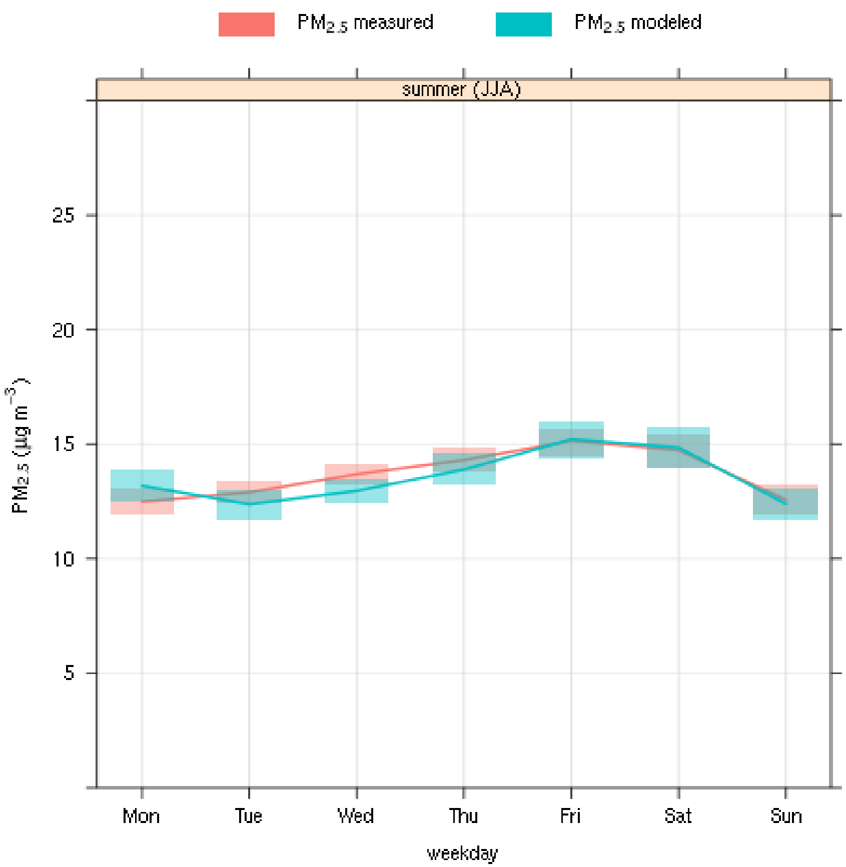




Conditional quantile (season) of daily averaged concentration for PM_{10} (left) and $PM_{2.5}$ (right) at AirBase background stations.

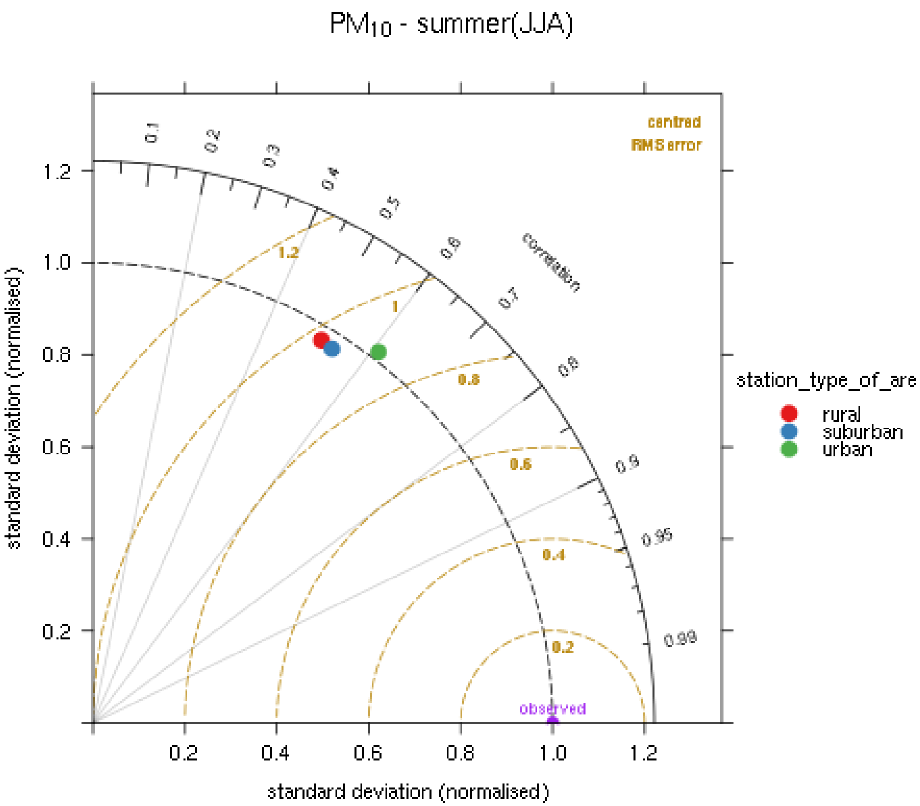
simulation results – summer period

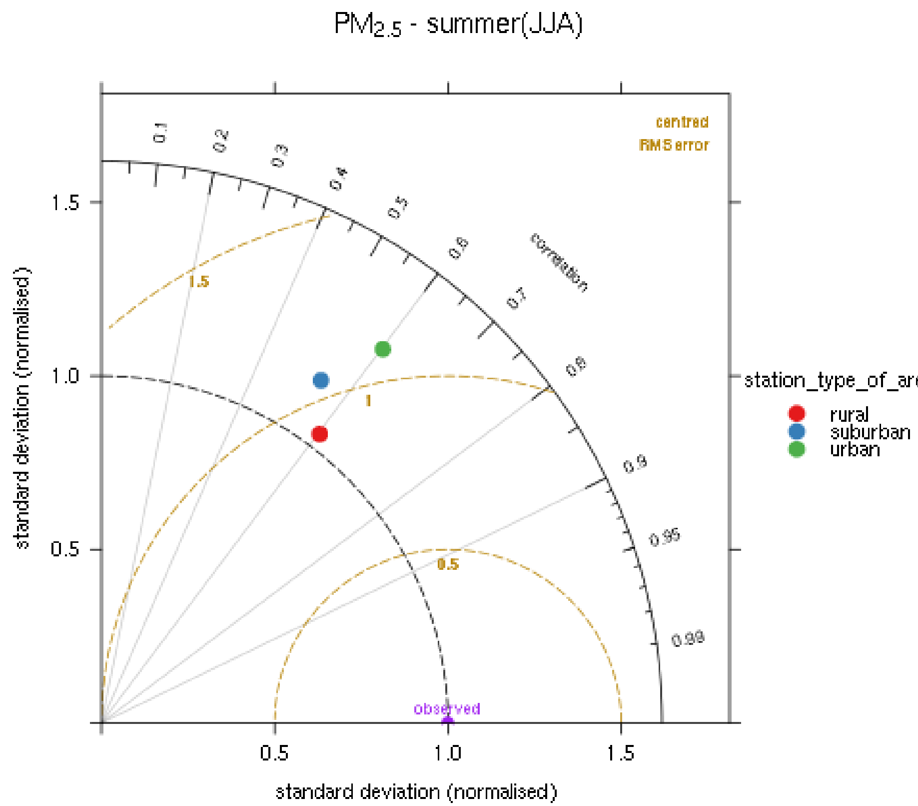




Weekday (season) averaged modeled concentration and the observed one of PM_{10} (left) and $PM_{2.5}$ (right) at AirBase background stations.

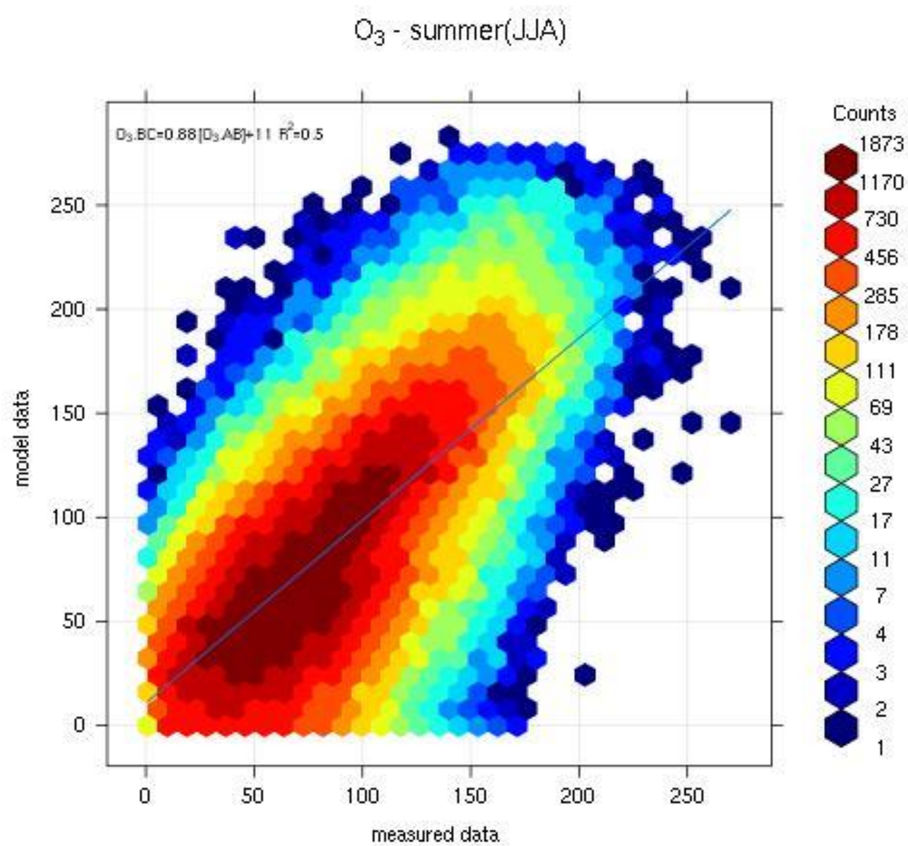
simulation results – summer period





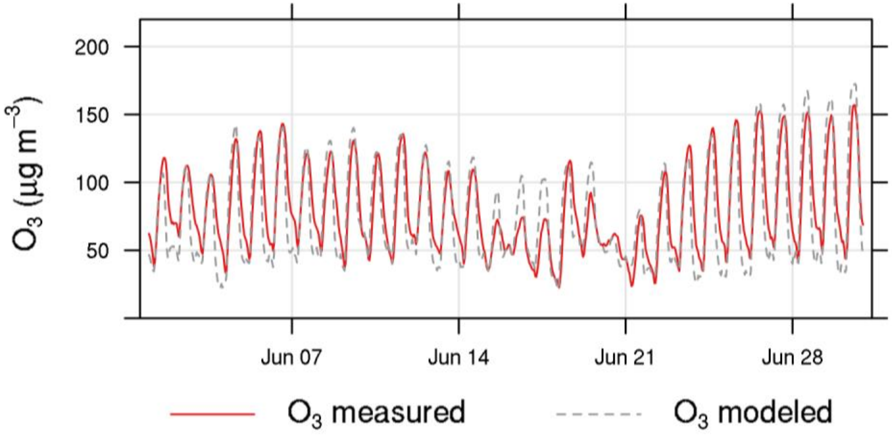
Taylor diagram for daily averaged PM_{10} (left) and $PM_{2.5}$ (right) ground concentration for the summer season

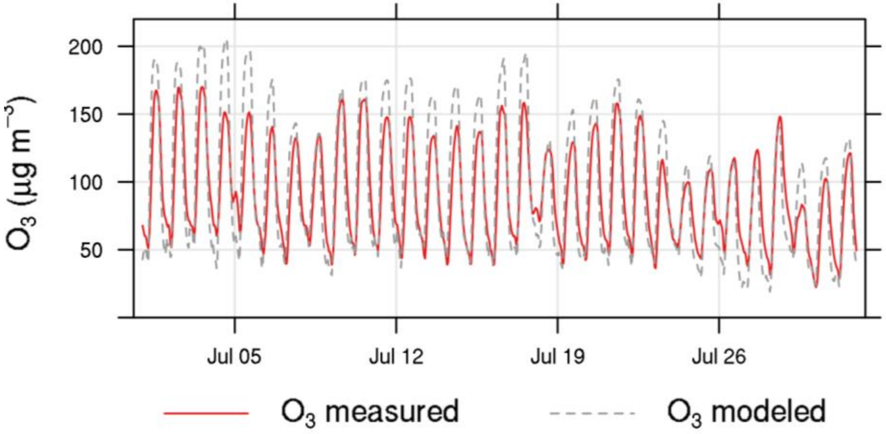
simulation results – summer period

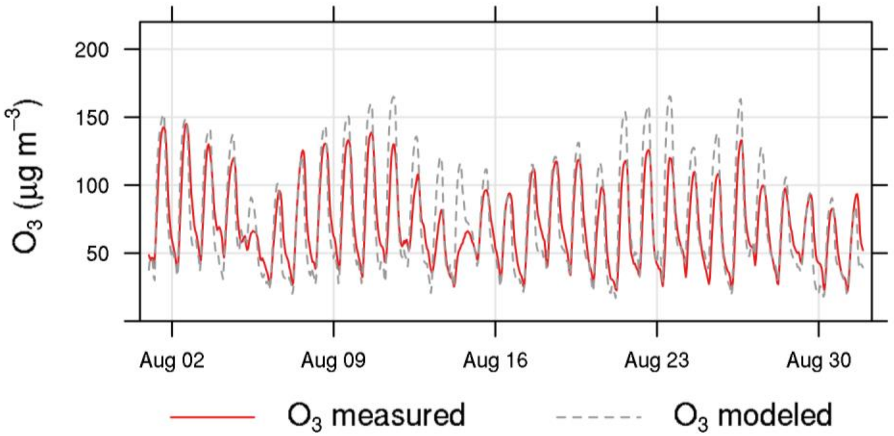


Modeled hourly averaged concentration vs the observed one for O_3 at AirBase background stations (scatter plot). Units are µg m^{-3}.

simulation results – summer period

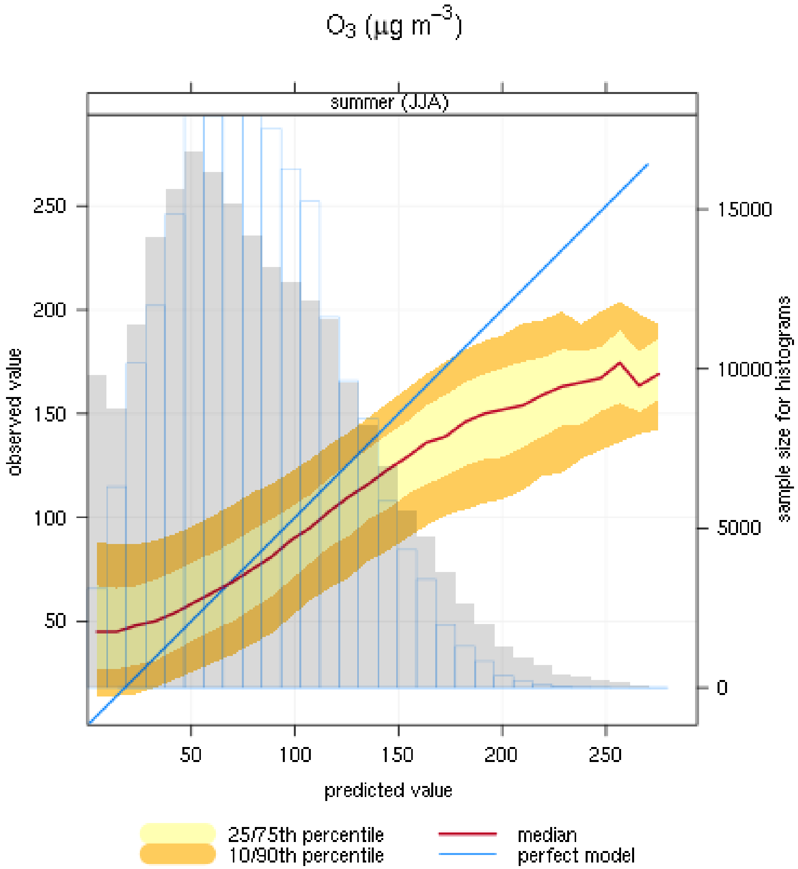


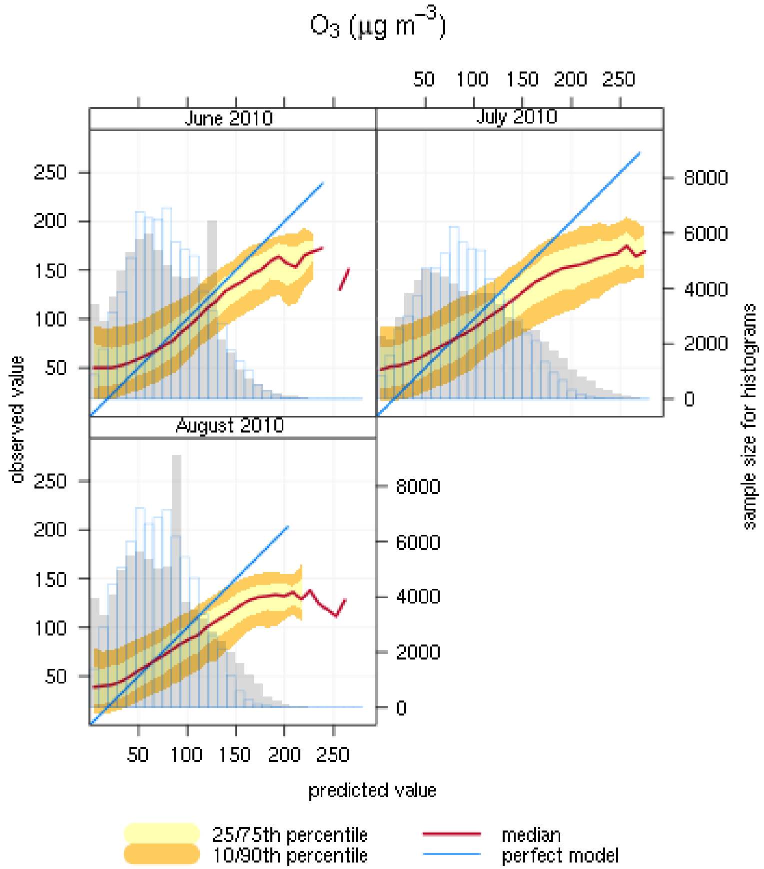




Time serie of modeled hourly averaged concentration (dotted line) and the observed one (red line) for O_3 at AirBase background stations.

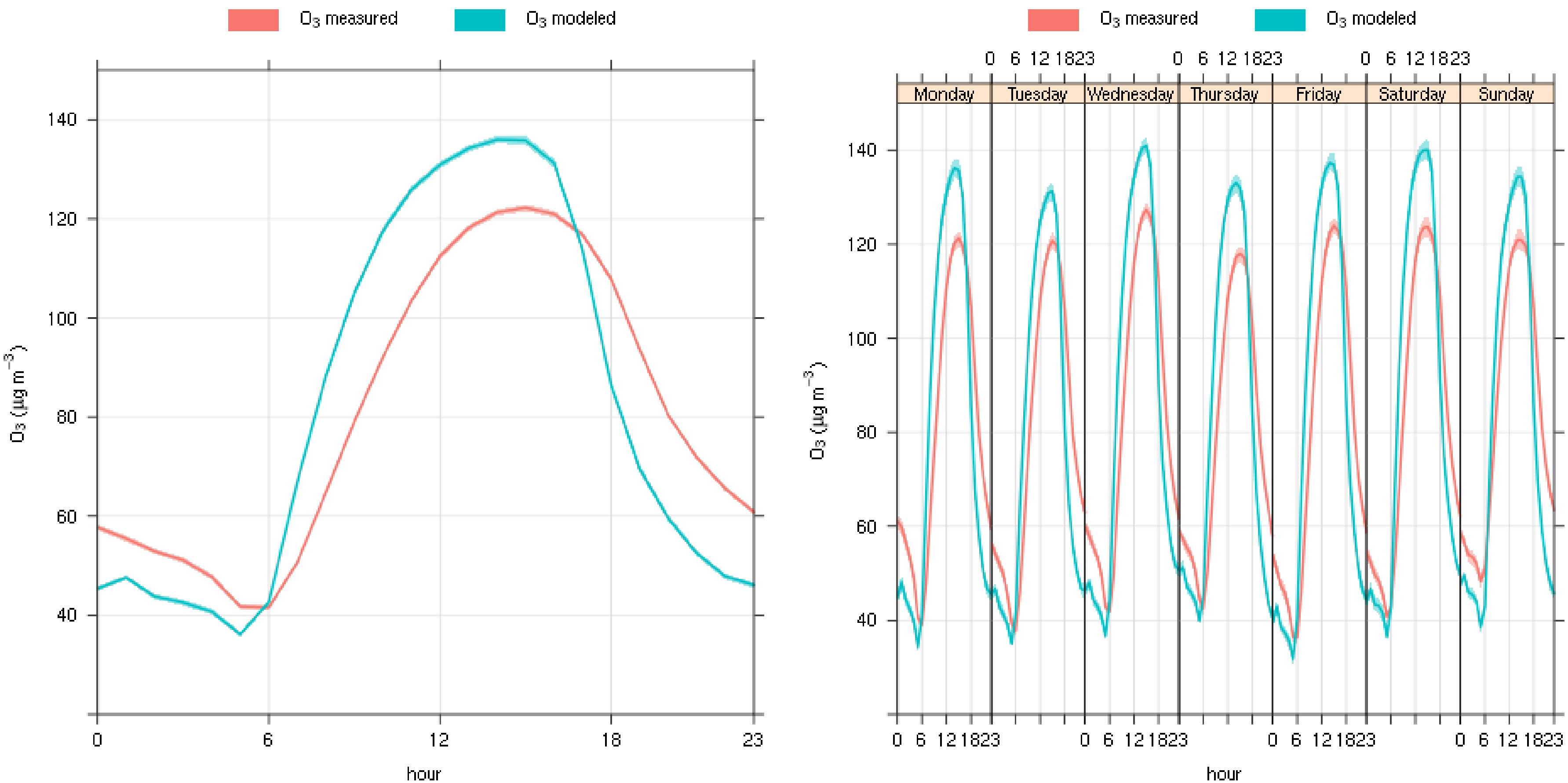
simulation results – summer period





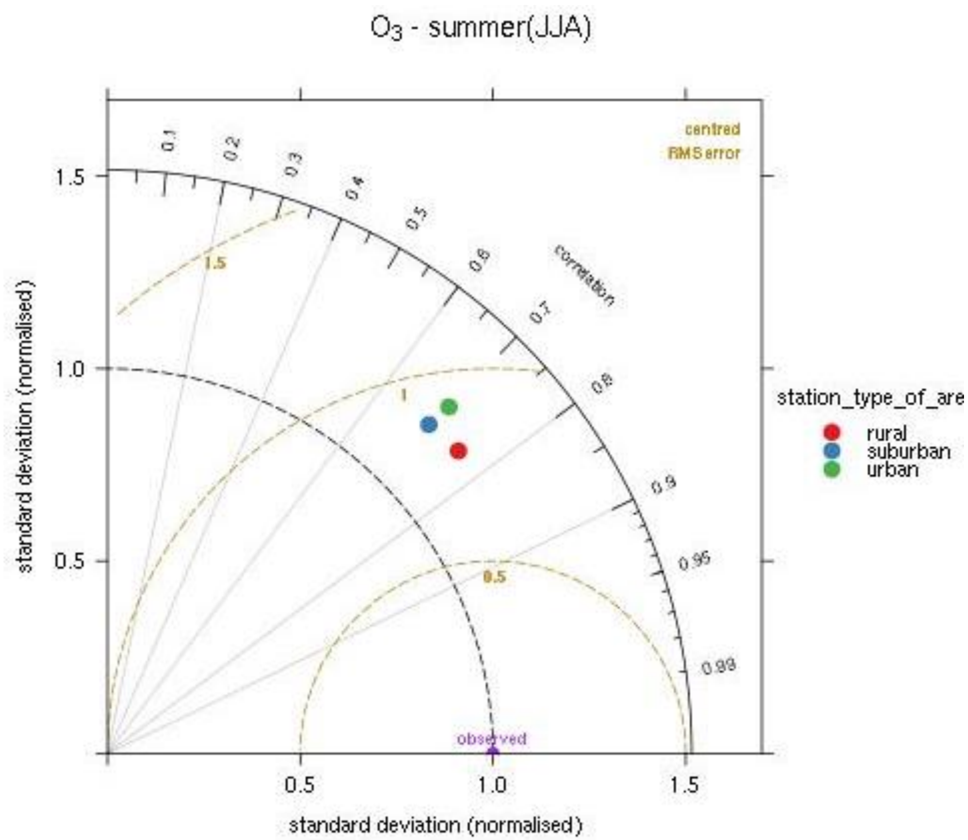
Conditional quantile (season) of daily averaged concentration for PM_{10} (left) and $PM_{2.5}$ (right) at AirBase background stations.

simulation results – summer period



Hour (left) and hour-day (right) hourly averaged modeled concentration and the observed one for O_3 at AirBase background stations.

simulation results – summer period



Taylor diagram for hourly averaged O_3 ground concentration for the summer season.

statistical indicators

winter period	PM_{10}[µg m^{-3}]			$PM_{2.5}$[µg m^{-3}]		
	MB	**R**	**RMSE**	**MB**	**R**	**RMSE**
All stations	**-3.7**	**0.6**	**21.4**	**-2.6**	**0.6**	**18.4**
Rural	**-2.0**	**0.5**	**20.5**	**0.6**	**0.5**	**17.0**
Suburban	**-3.7**	**0.5**	**21.8**	**-12.0**	**0.4**	**25.3**
Urban	**-4.0**	**0.6**	**21.4**	**-3.07**	**0.6**	**18.16**

Mean statistical indicators for PM_{10} and $PM_{2.5}$ over winter period.

statistical indicators

summer period	PM_{10}[µg m^{-3}]			$PM_{2.5}$ [µg m^{-3}]			O_3 [µg m^{-3}]		
	MB	R	RMSE	MB	R	RMSE	MB	R	RMSE
All stations	**-4.4**	**0.6**	**10.0**	**-0.1**	**0.6**	**7.1**	**0.8**	**0.7**	**35.3**
Rural	**-5.0**	**0.5**	**10.6**	**-2.2**	**0.6**	**6.6**	**7.4**	**0.8**	**32.5**
Suburban	**-5.4**	**0.5**	**10.5**	**-1.0**	**0.5**	**7.9**	**-4.8**	**0.7**	**36.5**
Urban	**-3.9**	**0.6**	**9.7**	**0.9**	**0.6**	**7.3**	**0.3**	**0.7**	**35.9**

Mean statistical indicators for PM_{10}, $PM_{2.5}$ and O_3 over summer period.

conclusion

- **For PM_{10} and $PM_{2.5}$ the correlation coefficiente is 0.6, both in the winter than in the summer period. Value reported in literature range beetwen 0.3 and 0.5 for the winter period, and beetween 0.4 and 0.7 for the summer period.**
  The model underestimate ground concentration, expecially the maximum values.

- **For O_3, the correlation coefficiente is 0.7. Value reported in literature range beetwen 0.6 and 0.8.**
  The model overestimate daily maximum ground concentration, that is reached with growth faster than in the observations.

- **Modeling performance are comparable with that of the COPERNICUS ensamble model.**
- **Further improvement in emissions data and model parameterization could led to best model performance.**

Thank you for your attention