Improvements of air quality simulations of particulate matter in the Iberian peninsula with road dust resuspension and dust emission modules

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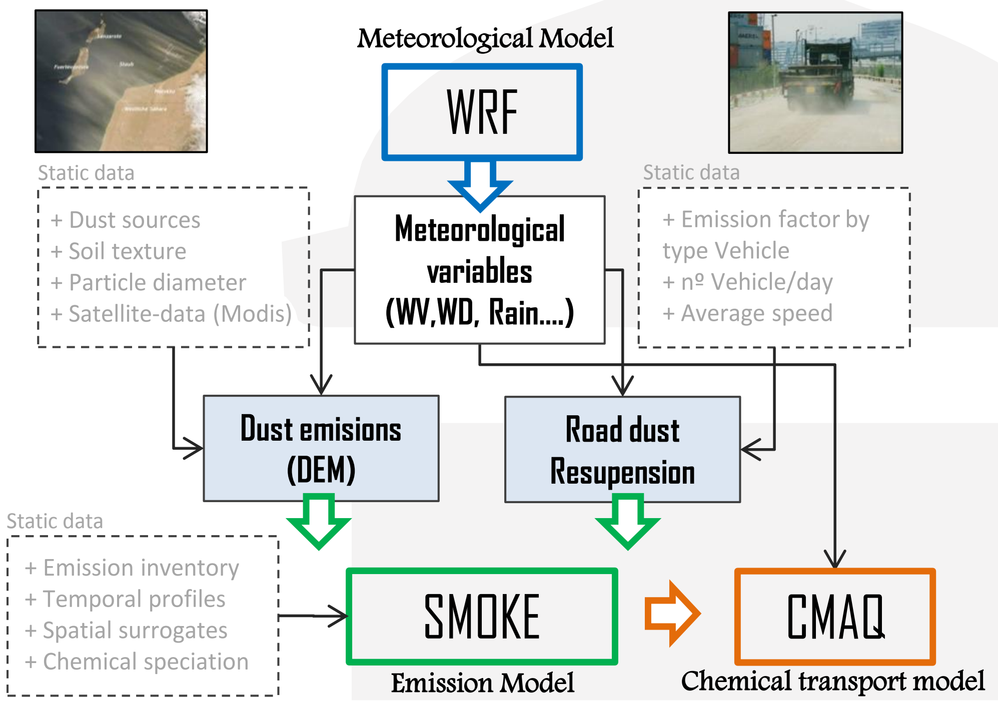
Abstract

The Mediterranean Basin is one of the most sensitive zones in the planet to air pollution. Besides anthropogenic emissions, the ***Iberian Peninsula*** is affected by natural particule matter (PM) sources. Dry weather conditions allow road dust to be resuspended by vehicle-induced turbulence. These emissions may be as important as those directly emitted by vehicles (combustion and from road abrasion and tyre and break wear processes). In addition, it is widely documented that crustal particles transported from the ***Saharan Desert*** may contribute significantly to ambient PM concentration in ***Madrid***. This poster summarizes the methodology and results of the implementation of a module to account for these sources –not included in current emission inventories- into the Eulerian air quality model **CMAQ** (*Figure 1*). Comparison of predicted PM concentrations with ambient air quality measurements and satellite observation point out that this module clearly improves the performance of the standard **CMAQ** version.



Meteorological Model

WRF

Meteorological variables (WV,WD, Rain….)

Static data

+ Dust sources
+ Soil texture
+ Particle diameter
+ Satellite-data (Modis)

Static data

+ Emission factor by type Vehicle
+ nº Vehicle/day
+ Average speed

Dust emisions (DEM)

Road dust Resupension

Static data

+ Emission inventory
+ Temporal profiles
+ Spatial surrogates
+ Chemical speciation

SMOKE

Emission Model

CMAQ

Chemical transport model

Methodology

Dust emissions from natural sources (DEM)

A domain consisting of ***124 x 108*** cells with ***48 x 48 km²*** spatial resolution, centred at ***34°20'N, 9°18'E*** has been used in order to capture synoptic features and general circulation patterns (*Figure 2*). The implemented dust sources spatial distribution follows the same scheme than the ***GOCART*** model (Chin et al., 2000). Simulations were conducted for the entire month of July 2007. The dust emission scheme incorporated by DEM is the one described in Gillette and Passi (1988). This scheme provides an equation for the estimation of the vertical flux of dust (***F***):

$$F = C\,S\,S_p W_{10m}^{2}(W_{10m} - U_t) \text{ if } W_{10m} > U_t$$

F = vertical flux of dust
C = *empirical coefficient (1 μg s² m⁻⁵)*
S = *source function (unitless)*
S_p = *fraction of each size class*
W_{10m} = *horizontal wind speed at 10m (m/s)*
U_t = *threshold velocity (m/s)*
D_p = *Diámetro partícula (m/s)*
ρ y ρ_a = Densidad de la partícula y el aire
w = humedad

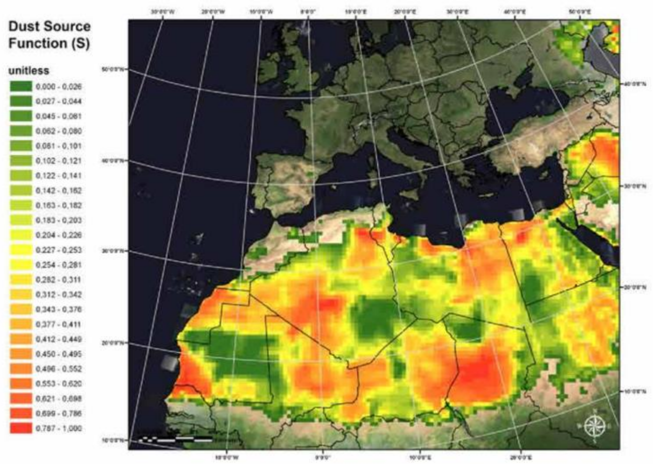


Figure 2. *Geographic distribution of the dust source function*

$$u_{t,0} = \begin{cases} u_{t,0}\,(1.02 + 0.2\log_{10} w), & \text{if } w < 0.5 \\ \infty & \text{if } w > 0.5 \end{cases}$$

$$u_{t,0} = \frac{0.0013}{\sqrt{1.928\left(1331\,D_p^{1.56} + 0.38^{0.092}\right) - 1}}\sqrt{\frac{\rho p g D_p}{\rho_a}}\sqrt{1 + \frac{0.006}{\rho p g D_p^{1.56}}}$$

DEM is integrated through an off-line approach, which means that it can be executed independently of the rest of the emissions. Dust particles (from 0.1 to 10 μm diameter) and were grouped into 5 size bins (de la Paz et al, 2013).

Conclusions

This paper presents the implementation and application of a dust module (**DEM**) into the **WRF-SMOKE-CMAQ** mesoscale modelling system (**AQM**). Two locations strongly affected by dust transport were the **DEM** module successfully captures the Saharan influence, improving thus the PM_{10} predictions of CMAQ alone. (*Figure 4a*). A reasonable reproduction of the geographical patterns of the dust transport process (*Figure 4b*)

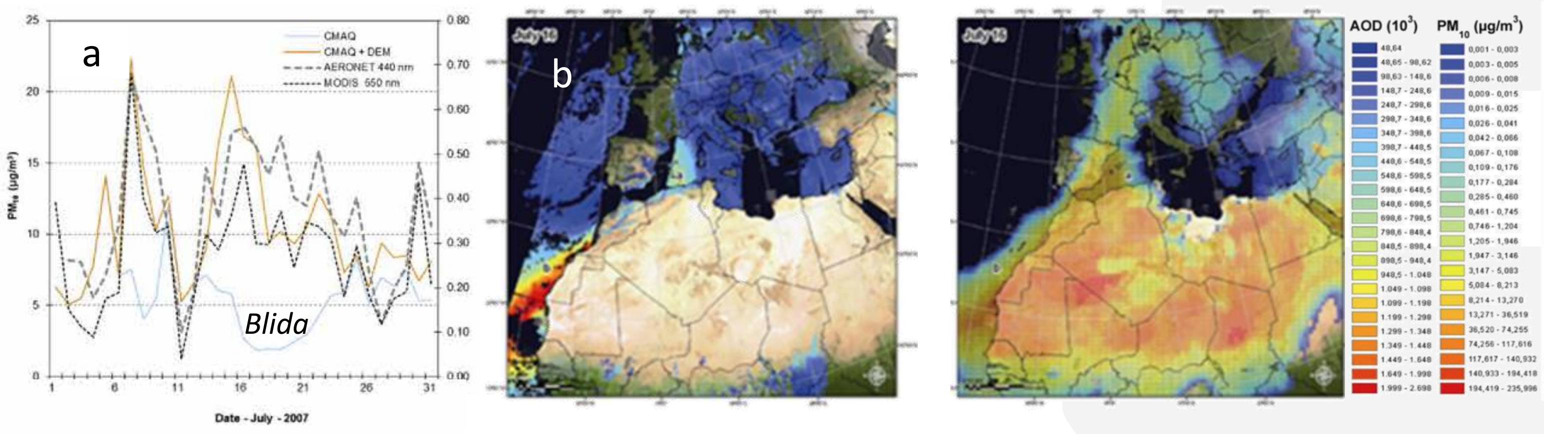


Figure 4. *(a) Temporal and (b) spatial AOT/PM_{10} comparison*

Acknowledgements

- ***Madrid City Council*** for providing the meteorological and air quality data.
- The **TECNAIRE-CM** scientific programme is funded by the Directorate General for Universities and Research of the Greater Madrid Region (S2013/MAE-2972)

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Road Dust emissions from traffic

The modeling domain is centered in the region of Madrid and comprises ***40*** x ***44*** cells with **1 × 1 km²** spatial resolution (*Figure 3*). The calculation of the contribution of ***PM resuspension*** (including suppression by rain) to PM_{10} ambient levels was implemented by means of as a scaling factor inside the emission model. Emissions from resuspension were calculated by vehicle type using mobility and traffic data for the Madrid urban area. It is assumed that the vehicle weight is the most influential factor The results of the air quality model were compared against observations aided by statistical indicators of performance.

$$E = K\,(SL)^{0.91}\,(W)^{1.02}$$

E = PM_{10} emission in $gVKT^{-1}$
K = *particle size multiplier* (g VKT^{-1})
sL = silt load (g m^{-2})
W = *average weight vehicle of the fleet (tons)*

$$EF_{global}\sum_{i=1}^{5}(veh\ km/day)_i = \sum_{i=1}^{5}EF_i(veh\ km/day)_i$$

$$EF_i = EF_{global}\,Ratio_i$$

VehicleType	Ratio (EF_i/EFreference)	EF (mg/veh·km)
Passenger cars	1.00	65.30
Taxis	1.00	65.30
Light duty vehicles	3.56	232.73
Trucks	19.86	1296.70
Motorcycles	0.09	5.84

Table 1. *Resuspension average emission factors*

Figure 3. *Domain simulation*

The precipitation threshold is set at **0.254 mm/h**. It is assumed that resuspension of PM recovers after between 2 to 4 hours from the time rain ceases (de la Paz et al., 2015).

The resuspension scheme was initially tested at microscale using the **OSPM street-canyon model**. Predicted PM_{10} concentrations with resuspension were much closer to observations than those without resuspension in specific streets where experimental data was available. Then it was implemented in **CMAQ**, substantially improving PM_{10} predictions (increasing annual average concentration up to 9 μg m^{-3}) (*Figure 5*)

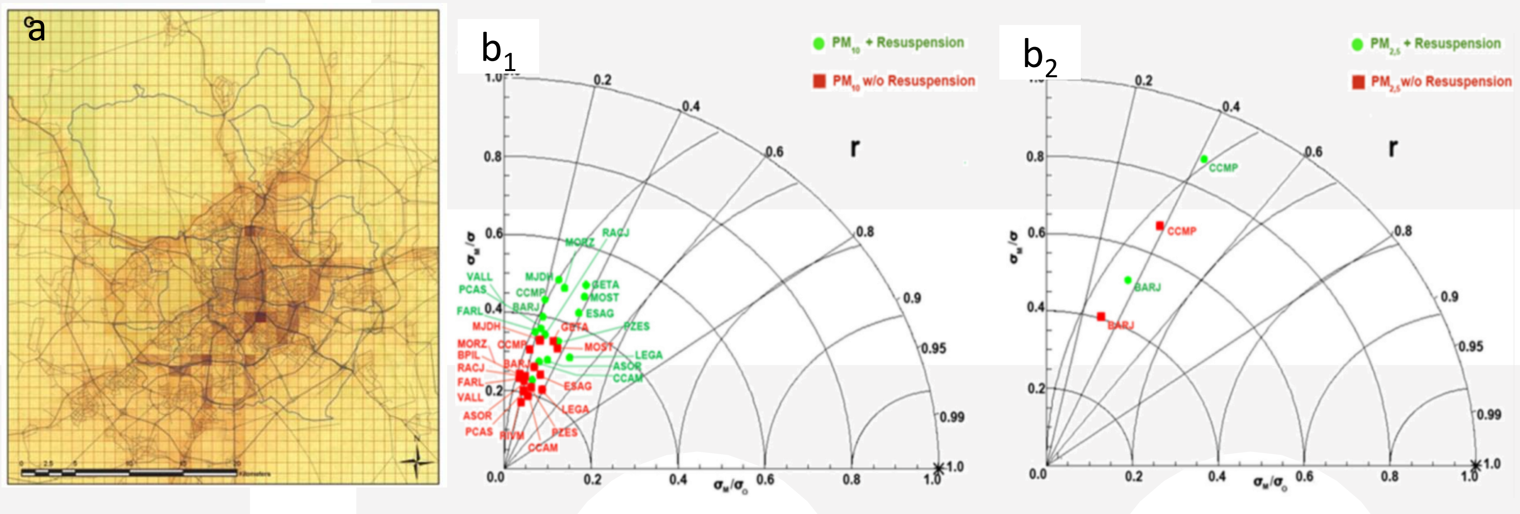

Figure 5. *(a) CMAQ [w resusp - w/o resusp]. (b_1) Taylor PM_{10} (b_2) Taylor $PM_{2.5}$*

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