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Estimation of wind blown dust emissions in Europe and its vicinity

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ABSTRACT

The assessment of the wind blown dust emission for Europe and selected regions of North Africa and Southwest Asia was carried out using a mesoscale model. The mesoscale model was parameterized based on the current literature review. The model provides data on PM_{10} emission from several dust reservoirs (anthropogenic, agriculture, semi- and natural) with spatial resolution of 10×10 km and temporal resolution of 1 h. The spatial variability of PM_{10} emission depends on soil texture, land cover/land use as well as meteorological conditions. Lands covered with water or permanently wet were excluded from the model. The land covered with vegetation is treated as dust reservoir whose dust emission capacity depends on the type of vegetation and cover. The dust reservoirs are divided into reservoirs with stable and unstable surface. The changes of emission in time depend on meteorological parameters.

The wind blown dust emission should be treated as a non-continuous spatio-temporal process. The emissions are estimated with high uncertainty. The estimated PM_{10} yearly total load emitted by wind from the European territory is highly differentiated in space and time and is equal to 0.74 Tg. The total load of PM_{10} emitted by wind from North African and Southwest Asian land surface located in the vicinity of European boundaries is assessed as nearly 50% (0.43 Tg) of the total load estimated for the whole Europe.

The average yearly PM_{10} emission factor for Europe was estimated at 0.139 Mg km^{-2}.

The PM_{10} emission from agricultural areas is estimated at 52% of the total wind blown emission from the domain of the European Union project "Improving and applying methods for the calculation of natural and biogenic emissions and assessment of impacts to the air quality" - NatAir.

PM_{10} emission factor for natural areas of Europe is estimated at 0.021 Mg km^{-2}. Appropriate factors for agricultural areas and anthropogenic areas are 0.157 Mg km^{-2} and 0.118 Mg km^{-2}, respectively. The latter two factors are probably underestimated due to omitting in the model of other dust emission mechanisms than aeolian erosion.

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1. Introduction

The development of the strategy for Cleaner Air for Europe (CAFÉ) has indicated a necessity of a detailed investigation on how the natural sources of air pollutants contribute to the quality of the air in Europe. Wind erosion has been recognized as an important geomorphic factor, which is responsible for the generation of dust emission. However, its role in the shaping of the dust concentration in the air has never been thoroughly studied and assessed. The mechanisms of dust emissions from the earth surface are comprehensive and do not restrict only to the wind activity Within the recent years many models have been developed to describe the phenomena of soil erosion and subsequent emission of dust to the atmosphere (Gillette and Passi, 1988; Hagen, 1991; Marticorena and Bergametti, 1995; Nickovic and Dobricic, 1996; Marticorena et al., 1997; Shao and Leslie, 1997; Wang et al., 2000; Shao, 2001; Zender et al., 2003; Vautard et al., 2005). While there is general agreement

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Table 1
Spike emission factors for unstable soils [g m^{-2}].

Soil texture	10-m Wind Speed [m s^{-1}]						
	8.9–11.1	11.1–13.4	13.4–15.6	15.6–17.8	17.8–20.0	20–22.3	22.3–24.5
Coarse	0.026	0.023	0.058	0.043	0.117	0.106	0.138
Medium	0.364	0.271	0.567	0.365	0.880	0.717	0.843
Medium fine	0.318	0.321	0.868	0.695	2.022	1.953	2.668
Fine	0.393	0.334	0.797	0.582	1.574	1.435	1.872
Very fine	0.052	0.040	0.087	0.058	0.143	0.119	0.143

about the factors which should be included into the model of the aeolian erosion mechanisms, some differences occur which refer to the scale of the model application and methods of its parameterisation, including the methods for determining the values of individual factors.

The local models of wind erosion and dust emission can be tackled based on field measurements and wind tunnel experiments (Hagen et al., 1995; Warren, 2000). The mesoscale models and underpinned physical models need less or more spatially aggregated values on: soil characteristics, land cover characteristics and meteorological characteristics which partially depend on the first two ones (Draxler et al., 2001; Shao, 2001; Alfaro and Gomes, 2001; Zender et al., 2003). The values of the parameters must be provided in an adequate spatial and temporal resolution which is reasonable in physical sense (the model is still applicable), and in technical sense (the calculations are feasible within the limits imposed by the software and hardware).

The wind erosion emission results from the soil grain abrasion as well as from the deflation of the abrasion products or materials deposited on the earth surface. The emission from abrasion is a result of the saltation process (Shao, 2001) and the so-called sandblasting process (Alfaro and Gomes, 2001). Dust production models address the deflation of the abrasion products. The deflation of other materials called resuspension is resolved only partially (Loosmore, 2003).

A separate issue arises when it is necessary to distinguish between the natural and the anthropogenic emission.

The wind blown erosion emission originated from anthropogenic areas should be considered as an anthropogenic emission due to involving mechanisms other than wind into the process of dust production (Pollack et al., 2005).

The effort to develop spatially and temporally resolved databases on natural dust emissions for the present and future years was undertaken by the authors within the project entitled "Improving and applying methods for the calculation of natural and biogenic emissions and assessment of impacts to the air quality" - NatAir conducted within the Six Framework Programme of the Research and Technology Development of the European Union (EU FP 6). This task required adapting one of the existing dust emission models and developing a complete set of data with spatial and temporal resolution adequate to the applied model in the scale of Europe.

The approach presented in this paper enables to separate the natural emission from the anthropogenic emission only partially. The dust emission from the deflation process is partially natural (mechanism) and partially anthropogenic (dust source). Nevertheless, the obtained results allow to make a preliminary assessment of the wind blown dust contribution to the observed concentrations of PM_{10} over the territory of Europe.

2. Approach/method

The dust entrainment into the atmosphere has been modelled based on the approach developed within the Western Regional Air Partnership (WRAP) project (Mansell et al., 2004). The area is divided into potentially erodible and unerodible surface (land under water or permanently irrigated). The erodible surface is divided into dust reservoirs with stable and unstable surface (Li et al., 2004) also called 'limited' or 'unlimited'. The limited dust reservoirs contain loose particulate matter particles lying on stable surfaces and hence give rise to small quantities of wind blown emissions. An additional force is needed to refill such reservoirs, e.g.: movement of vehicles, human beings or animals. Unlimited dust reservoirs contain loose particles in very large quantities. For this type of surface disruption is most frequently observed. Dry, arable soil is a typical example of such a reservoir. The assessment of this parameter was carried out based on the land use data. The emission from the erodible surface depends on two main factors: threshold wind velocity and potential flux of the horizontal emission. Within the implemented method, the threshold wind velocity defines the inception of the emission process as a function of the wind velocity and the surface characteristics. The

Table 2
Spike emission factors for stable soils [g m^{-2}].

Soil texture	10-m Wind Speed [m s^{-1}]						
	8.9–11.1	11.1–13.4	13.4–15.6	15.6–17.8	17.8–20.0	20–22.3	22.3–24.5
Coarse	0.006	0.014	0.017	0.028	0.052	0.068	0.079
Medium	0.080	0.163	0.172	0.240	0.392	0.456	0.483
Medium fine	0.070	0.193	0.262	0.455	0.906	1.246	1.536
Fine	0.087	0.201	0.241	0.381	0.704	0.915	1.076
Very fine	0.012	0.024	0.026	0.038	0.064	0.076	0.082

Table 3
Emission rate for unstable soils [$g\,m^{-2}\,h^{-1}$].

Soil texture	10-m Wind Speed [$m\,s^{-1}$]						
	8.9–11.1	11.1–13.4	13.4–15.6	15.6–17.8	17.8–20.0	20–22.3	22.3–24.5
Coarse	0.150	0.184	0.157	0.226	0.361	0.303	0.338
Medium	1.984	2.127	1.356	1.836	2.618	2.031	2.025
Medium fine	1.728	2.526	2.078	3.495	6.030	5.539	6.418
Fine	2.142	2.632	1.917	2.923	4.689	4.068	4.500
Very fine	0.282	0.325	0.226	0.312	0.444	0.365	0.354

strength of the emission is affected by the wind speed (wind threshold velocity) and the soil characteristics. Within the applied solution, the wind threshold velocity was assumed as constant for the whole territory studied in the NatAir project, i.e. at the level of 8.9 $m\,s^{-1}$. This assumption is a compromise between the requirements of a physical model and the parameterisation possibilities of the threshold friction velocities for the whole variety of soils and land within the NatAir domain. The selected value is located within the range of literature data, i.e. 6–13 $m\,s^{-1}$ obtained for desert areas and arable lands and has already been applied in previous studies (Mansell et al., 2004).

The horizontal fluxes were differentiated, taking into account the wind velocity, soil grain composition (textural groups according to the classification used by Food and Agriculture Organization – FAO) as well as the state of the surface (Tables 1–4). It was assumed that each erosion episode started from a high emission flux (spike emission) followed by steadily decreasing lower emission. The potential fluxes cited in tables below were calculated based on values prepared for the needs of the ENVIRON/RMC model (Mansell et al., 2004), which is based on dependencies described by Alfaro and Gomes (2001).

Some changes were necessary in the presented values, due to the application of the FAO classification for the description of the textural group. The original values were related to the classification of soil texture used by United States Department of Agriculture (USDA), and therefore required recoding and recalculation.

Horizontal emission was calculated according to Eq. (1):

$$E(\text{g/unit area}) = \{\text{land area}, \text{m}^2\} \times \Big\{[\text{spike emission rate}, \text{g m}^{-2}] + \Big[(\text{duration of erosion event}, \text{h}) \times \Big(\text{emission factor}, \text{g m}^{-2}\,\text{h}^{-1}\Big)\Big]\Big\} \quad (1)$$

where erosion event – a period of time in which meteorological parameters enable erosion (1 h or 10 h depending on the surface stability); land area – area of the dust reservoir reduced by the factor of vegetation cover; spike emission and emission factor – as presented in Tables 1–4.

Vertical emission of PM_{10} was calculated as follows (Eq. (2)):

$$\text{Vertical emission}_{(\text{g/unit area})} = E \times \text{ALFA} \quad (2)$$

where Alpha – dimensionless factor (ratio of the vertical and horizontal emission) that depends on: Soil texture – clay content (Marticorena and Bergametti, 1995); Wind friction velocity (Gillette and Passi, 1988).

Land use/land cover data were precompiled based on the CORINE2000[1] and GLC2000[2] data as a 1 km × 1 km grid (Koeble, 2006). For the needs of the PM_{10} emission calculations, the land use data were reclassified into a set of dust reservoirs. Parameters of these reservoirs used for calculations are presented in Table 5.

The soil texture map was compiled as a raster of 10 km × 10 km resolution based on the European Soil Map of soil texture (Van Liedekerke and Panagos) and USGS[3] soil map (Webb et al., 2000). The unclassified soils of urban areas were coded as coarse soils.

It was assumed that dust reservoirs, i.e. potentially erodible surfaces, may be covered with vegetation but the area of such reservoirs is decreased by the vegetation cover factor and the vegetation debris factor. The applied factors are presented in Table 5.

The behaviour of a dust reservoir depends on meteorological parameters and the length of the erosion event.

The dust reservoirs of unlimited potential (with unstable soil surface) are able to emit dust for 10 successive hours while the reservoirs of limited potential (stable soil) only for 1 h. After these periods the reservoirs must be recharged to recover their dust emission potential. The necessary recharging time was assumed as 24 h.

The dust reservoirs are inactive during rain, when they are covered with snow or when the soil temperature is below zero. The dust reservoir remains inactive for 72 h after each rain or snow cover melting. Also after each freeze period, the dust reservoir is not active for the next 12 h. These periods are necessary for the reservoir to regain its dust emission capability.

All the above mentioned parameters which confine the behaviour of dust reservoirs were adopted following the results of the WRAP project (Mansell et al., 2004).

The meteorological parameters necessary to calculate the reservoir emission capability and the wind velocity field were calculated based on MM5 model[4] with a resolution of 24 × 24 km and interpolated to a 10 × 10 km grid used in the NatAir project.

[1] Acronym of the map of land cover and land use developed using the technical requirements defined by the European Union Project "Coordination of Information on the Environment", updated for year 2000.
[2] Acronym of the Global Land Cover 2000 project coordinated by Joint Research Center.
[3] Acronym of the United States Geological Survey.
[4] Acronym of the model designed to simulate or predict mesoscale atmospheric circulation – http://www.mmm.ucar.edu/mm5/mm5-home.html.

Table 4
Emission rate for stable soils [g m^{-2} h^{-1}].

Soil texture	10-m Wind Speed [m s^{-1}]						
	8.9–11.1	11.1–13.4	13.4–15.6	15.6–17.8	17.8–20.0	20–22.3	22.3–24.5
Coarse	0.034	0.076	0.090	0.096	0.182	0.233	0.332
Medium	0.513	0.848	0.909	0.778	1.364	1.578	2.066
Medium fine	0.628	1.009	1.416	1.486	3.159	4.304	6.586
Fine	0.643	1.051	1.293	1.244	2.454	3.162	4.612
Very fine	0.083	0.139	0.148	0.148	0.224	0.276	0.352

The area of each reservoir reduced by the vegetation cover/debris factor and summarized within one cell was used for calculating the PM_{10} emission load from one cell for each following hour, taking into account the limitations of the dust reservoirs behaviour mentioned earlier.

After the simulation, the results were adjusted to the results of the available national inventories.

The obtained set of tables allows characterizing the spatial and temporal distribution pattern of PM_{10} emissions in the NatAir domain.

To characterize the uncertainty of the simulation, three calculations were made:

- a minimum value assessment using ALPHA coefficient in the range of 10^{-5}–10^{-6}, selected based on a literature survey (Marticorena et al., 1997; Vautard et al., 2005);
- a maximum value assessment (first adjustment) using ALPHA coefficient in the range of 10^{-2}–10^{-3}, selected based on a comparison of the NatAir simulation with the selected national inventories of PM_{10} emission (Van Harmelen et al., 2004);
- the best value assessment (second adjustment) using ALPHA coefficient in the range of 10^{-3}–10^{-4}, selected after a simulation of the influence of wind blown dust emission on PM_{10} concentration in air with the application of the CHIMERE model carried out by Curci et al. (2007).

The simulations were carried out for four years, i.e. 1997, 2000, 2001 and 2003. The year 2000 was selected as the base year for the CAFÉ strategy development. The years 1997, 2001 and 2003 were selected as a base to develop the future scenario for the year 2010 due to the different meteorological conditions. The year 2003 was characterized by the broadly known "heat wave", so it could be used as an example of a dry year scenario, while the years 1997 and 2001 represented average meteorological conditions. The same land use/land cover patterns were assumed for each simulated year.

3. Results

Figs. 1–4 present the maps of the highest estimated total PM_{10} emissions. The spatial pattern of the emission is nearly the same. The spatial distribution is highly asymmetric. The applied classification is based on a nearly quintile scale. The emission was very small or unobserved

Table 5
Area correction factor due to the vegetation cover.

Reservoir code	Reservoir name	Total domain (%)	Domain without R0 (%)	Reservoir type	Surface type	Vegetation cover/debris correction factor			
						Full year	Dec–Feb	Mar–Sep	Oct–Nov
R0	Non dusting	40.03	5.51		0				
R1	Urban stable	0.66	0.98	A	Stable	0.070			
R2	Urban unstable	0.23	0.35	A	Unstable	1.000			
R14	Urban green areas	0.05	0.07	A	Unstable	0.070			
R211	Non-irrigated arable land	11.53	18.72	Ag	Unstable		1.000	0.085	0.269
R22	Fruits, olive, vineyards	4.31	6.96	Ag	Unstable		0.645	0.161	0.334
R23	Pastures	1.66	2.59	Ag	Unstable		0.269	0.085	0.112
R24	Mixed agricultural/natural/ built up	2.21	3.55	Ag	Unstable		1.000	0.334	0.645
R3	Forest	20.79	31.65	N	Stable	0.070			
R321	Grassland	6.88	10.89	N	Stable	0.195			
R322	Moors, shrubland, savanna	0.40	0.48	N	Stable	0.195			
R323	Sclerophyllous vegetation	0.44	0.69	N	Stable	0.700			
R324	Transitional woodland-shrub	1.06	1.59	N	Stable	0.070			
R331	Beaches, dunes, sands	2.14	3.55	N	Unstable	0.700			
R332	Bare rocks	4.46	7.31	N	Unstable	1.000			
R333	Sparsely vegetated areas, barren or sparsely vegetated	3.13	5.10	N	Unstable	0.700			
R334	Burnt areas	0.02	0.02	N	Stable	1.000			

A = Anthropogenic, Urban.
Ag = Anthropogenic, Agriculture.
N = Natural.

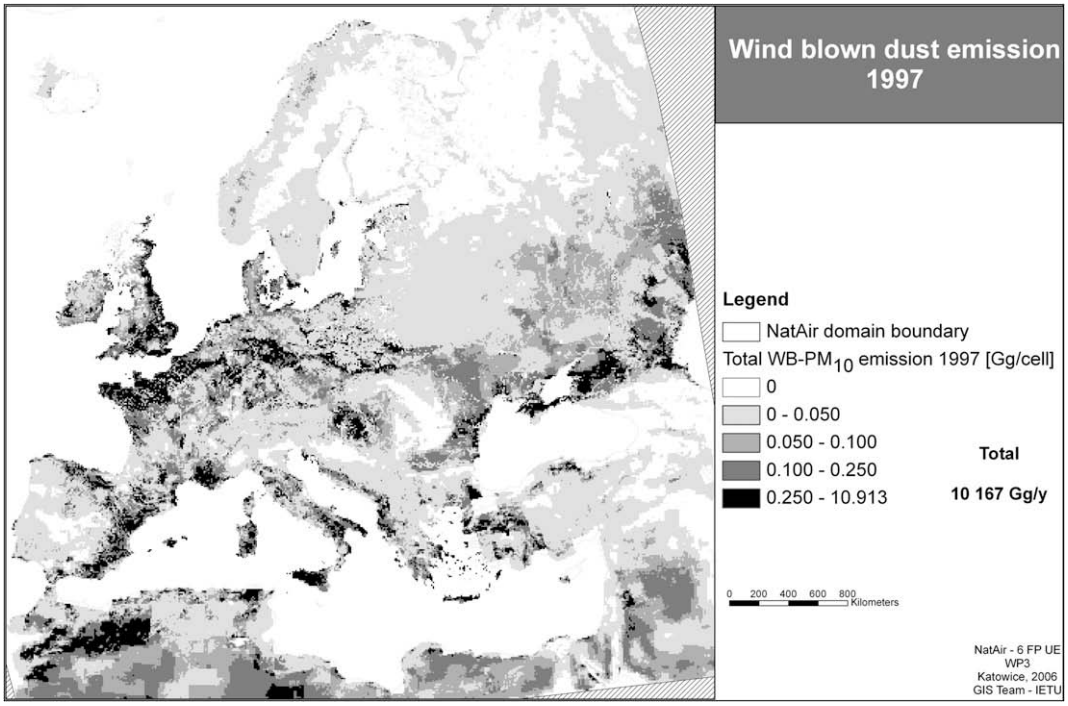


Fig. 1. The highest estimate of the total wind blown PM_{10} emission in 1997 [Gg/100km^2].

on about 40% of the area. The emissions above 2.5 Mg km^{-2} were observed on 20% of the area with sporadically occurring spikes. The main investigated reservoirs were located in North Africa and Southwest Asia. Within Europe the most important dust reservoirs were located in Spain, France, Italy, Greece, Ukraine, Russia and the United Kingdom. The presented maps for the years 1997 and 2003 (Figs. 1 and 4) indicate that the role of individual reservoirs

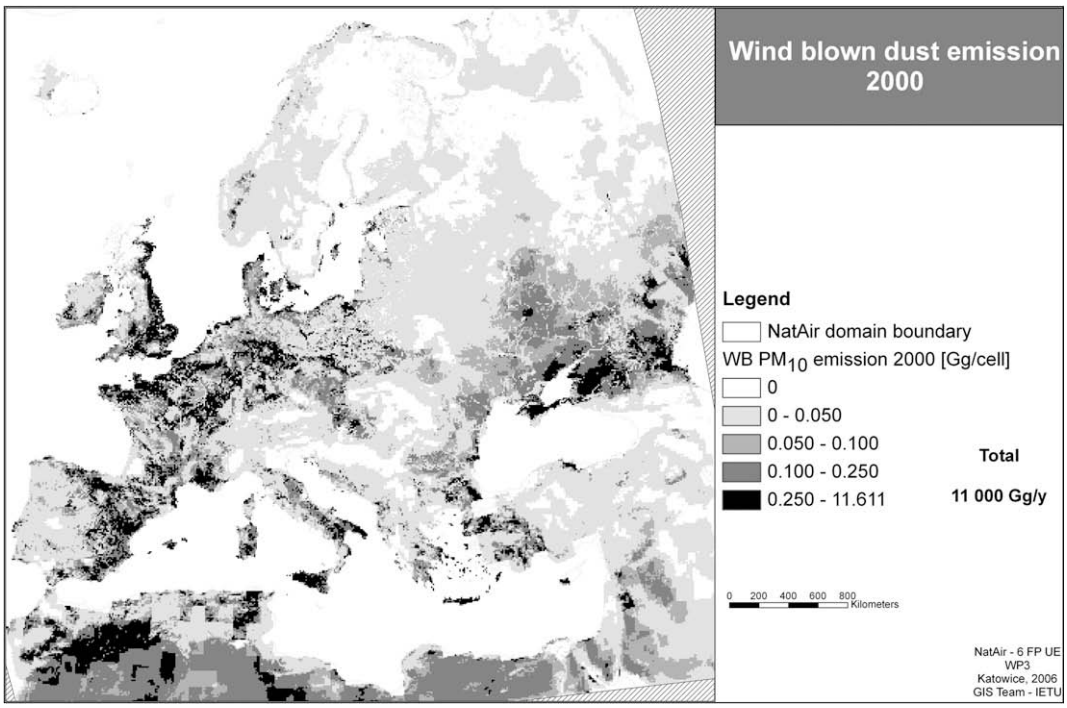


Fig. 2. The highest estimate of the total wind blown PM_{10} emission in 2000 [Gg/100km^2].

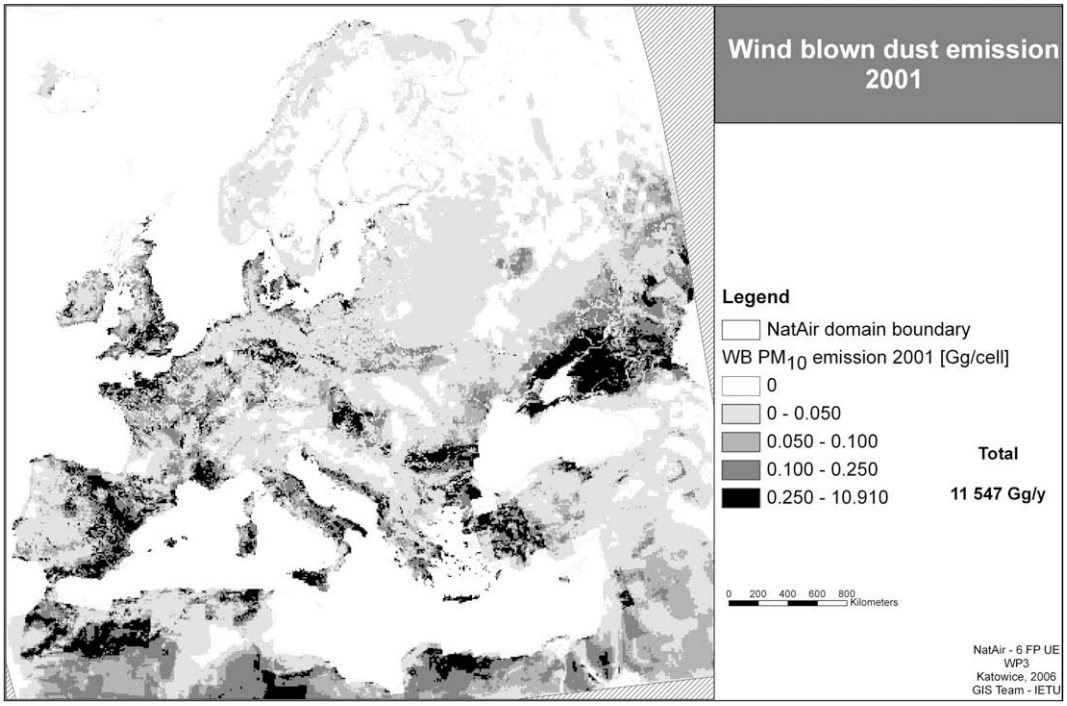


Fig. 3. The highest estimate of the total wind blown PM_{10} emission in 2001 [Gg/100km^2].

changes in time, depending on the meteorological conditions.

The differences can be observed in the spatial distribution pattern of the areas with zero emission (i.e. where the condition of the threshold wind velocity is not fulfilled) as well as in the emission intensity from a simulated grid cell. While the maximum values of local PM_{10} emission per cell are similar, the location

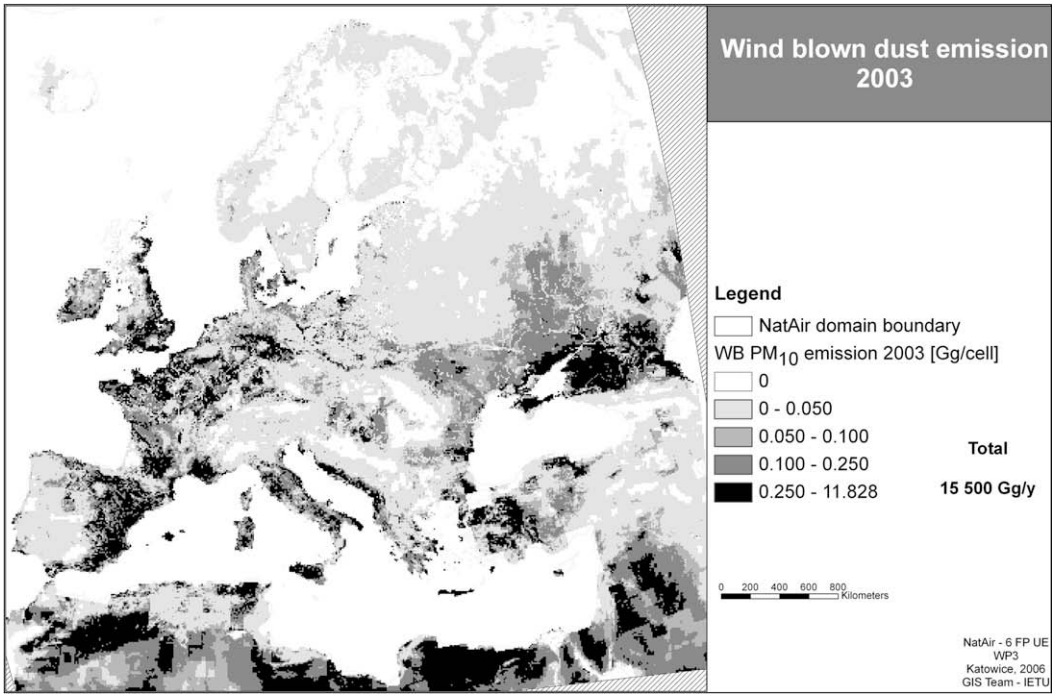
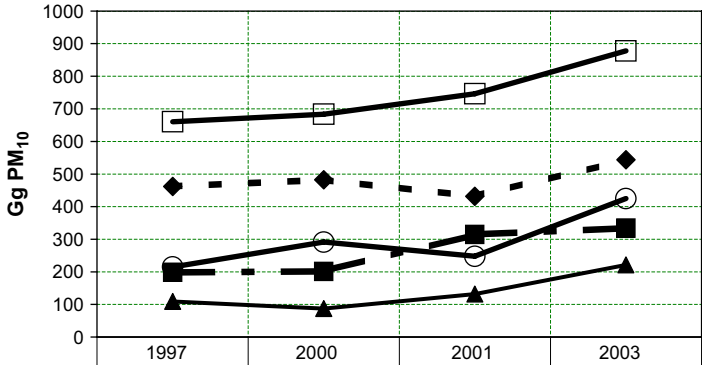


Fig. 4. The highest estimate of the total wind blown PM_{10} emission in 2003 [Gg/100km^2].



	1997	2000	2001	2003
EU25 (EU states in 2006)	462	482	432	544
Non EU European states	199	201	315	334
Europe	661	683	746	878
Southwest Asia	109	88	132	221
North Africa	215	291	248	425

Fig. 5. Changes of the annual wind blown PM_{10} load within NatAir domain based on the best estimate.

and area of reservoirs with high emission change in time.

Within the whole investigated domain an increase of the total PM_{10} emission in time was noted.

However, such tendency was observed only on large areas (Fig. 5), while locally, i.e. on the level of particular countries, it was not recorded. The wind blown PM_{10} emissions and the emission factors are referred separately

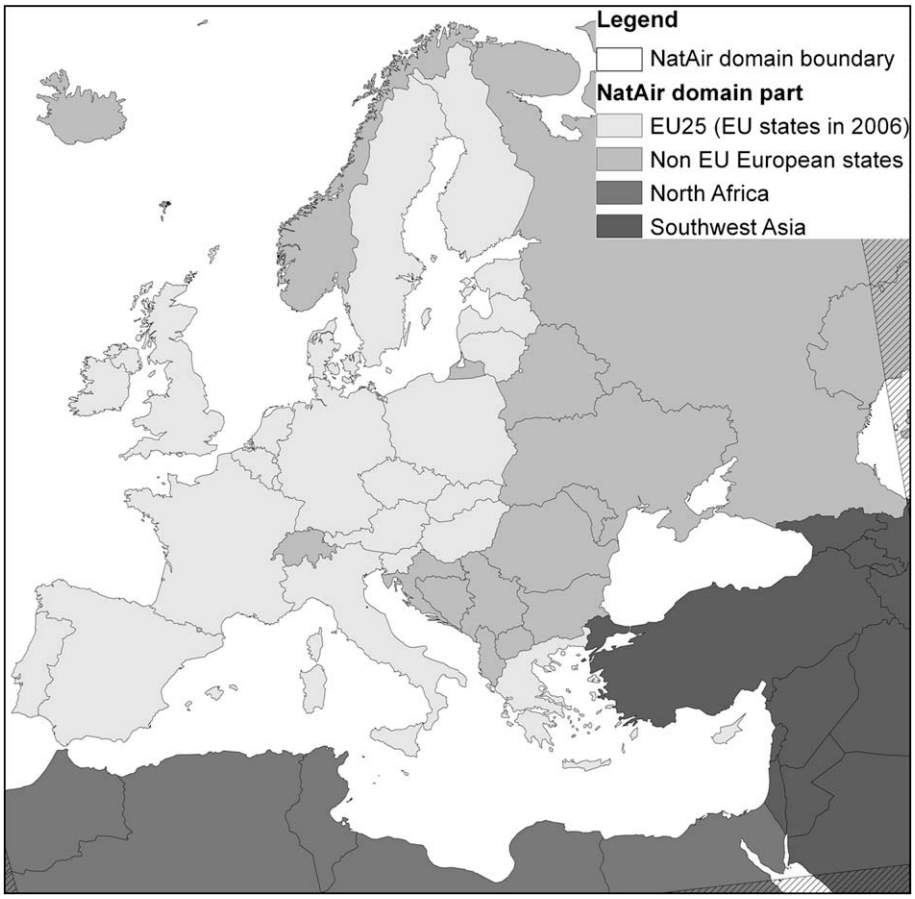
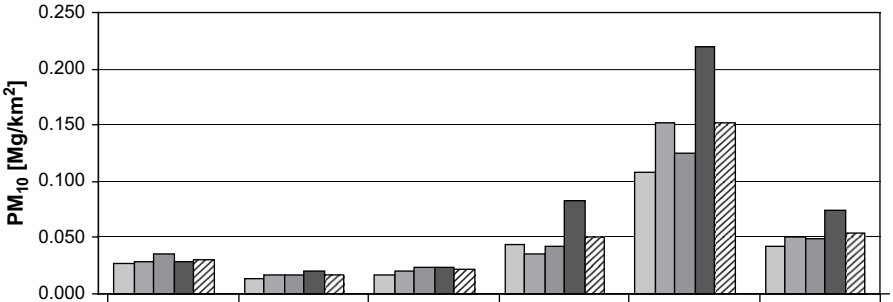


Fig. 6. Regions within the NatAir domain.



	EU25 (EU states in 2006)	Non EU European states	Europe	Southwest Asia	North Africa	NatAir DOMAIN
1997	0.027	0.013	0.018	0.044	0.109	0.042
2000	0.029	0.016	0.021	0.035	0.152	0.051
2001	0.035	0.017	0.023	0.042	0.125	0.048
2003	0.029	0.021	0.024	0.083	0.219	0.075
MEAN	0.030	0.017	0.021	0.051	0.151	0.054

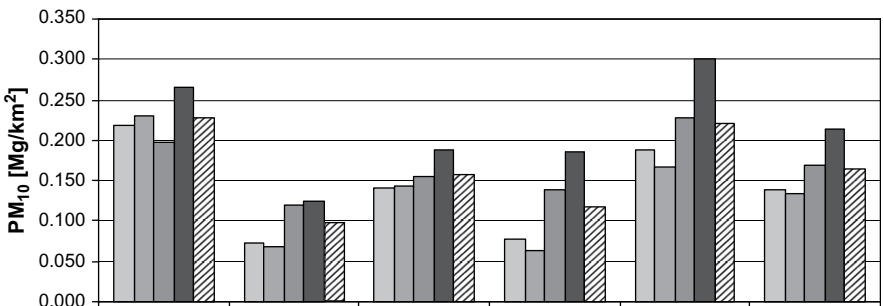
Fig. 7. Wind blown PM_{10} emission factors for the natural areas [Mg km^{-2}] based on the best estimation.

for different geographical regions of the NatAir domain in the tables and figures below. The boundaries of these regions are presented in Fig. 6.

The total mean yearly emission of PM_{10} for the whole NatAir domain was estimated on the level of 1.174 Tg (0.985–1.524 Tg). The main source of the wind blown PM_{10} emission is related to the anthropogenic reservoirs (agriculture and urban). The natural reservoirs constitute about 45% of the total emission load within the NatAir domain. But the contribution of the natural reservoirs in the wind blown dust emission from the European territory is lower. The average European emission factor for the natural reservoirs is estimated at the level of 0.02 Mg km^{-2}, which is 7 times lower than the African one (Fig. 7). Similar, however less distinct difference can be observed in the case of the emission factors for agricultural areas (Fig. 8).

The factors for urban areas represent an opposite relation (Fig. 9). The European emission factor is more than two times higher than the African one.

These factors indicate that in average the wind blown PM_{10} emission from the urban areas is intensive but its role in shaping the air quality is only local.



	EU25 (EU states in 2006)	Non EU European states	Europe	Southwest Asia	North Africa	NatAir DOMAIN
1997	0.218	0.072	0.140	0.078	0.189	0.140
2000	0.229	0.067	0.142	0.064	0.168	0.134
2001	0.197	0.121	0.156	0.138	0.229	0.168
2003	0.265	0.124	0.189	0.186	0.301	0.213
MEAN	0.227	0.096	0.157	0.117	0.222	0.164

Fig. 8. Wind blown PM_{10} emission factors for the agricultural areas [Mg km^{-2}] based on the best estimation.

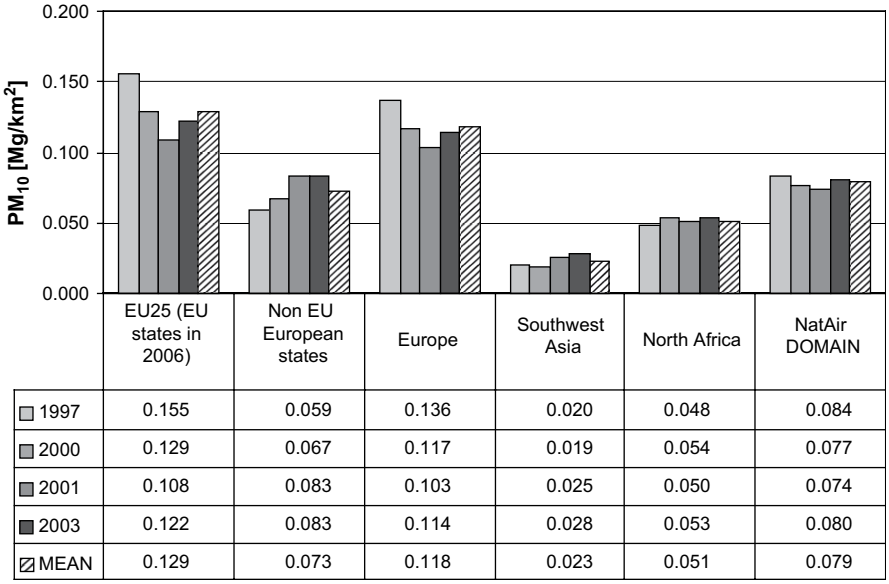


Fig. 9. Wind blown PM_{10} emission factors for the urban areas [Mg km^{-2}] based on the best estimation.

4. Uncertainties

The results of the separate simulations (best, minimum and maximum) are presented below. They differ in the range of three orders (Table 6).

The uncertainties of the obtained results can be divided into two groups:

- uncertainties related to the calculation of horizontal dust load from wind erosion;
- uncertainties related to the calculation of the vertical PM_{10} load from wind erosion and from deflation.

The main source of the uncertainty is related to the second group.

The uncertainties connected with the calculation of the horizontal emission of dust result from:

- assumed value of the wind threshold velocity, common for the whole domain – 8.9 m s^{-1} that can actually vary within broad limits;
- assignment of dust reservoirs as reservoirs with stable or unstable surface based only on the land use/land cover classification;
- application of the averaged factors for the area reduction due to the presence of the vegetation cover;
- application of soil texture map with too coarse resolution;
- application of an arbitrary assigned length of the emission period and recharge period for all reservoirs.

Table 6
Uncertainty of the wind blown PM_{10} emission in the NatAir domain.

Emission of PM_{10} [Gg y^{-1}]			
	Best aver.	Min.	Max aver.
EU25 (EU States in 2006)	480	4.3	5439
Non EU European states	262	2.0	3339
Europe	742	6.6	8778
Southwest Asia (part)	137	0.9	2213
North Africa (part)	295	2.1	4250
NatAir Domain	1174	10.0	15242

It has been assessed that the above listed sources of uncertainty are responsible for 25–50% of the possible variability of the dust horizontal emission observed in a particular type of the reservoir. It is known that the average time necessary to dry the soil surface differs between soil parameters, land cover and season. The reduction of uncertainty due to these reasons can be obtained by tackling of the model with the information on soil moisture (Fecan et al., 1999) which was not possible in the presented application of the selected dust emission model.

The highest uncertainty is related to the calculation of the ALPHA factor value, which is responsible for the conversion of the horizontal emission into a vertical one. The values of this factor vary in broad limits of one order and depend on the wind friction velocity and soil texture. The applied factor was established at the average level of 0.000×, whereas in literature it can vary from 0.00× to 0.00000× (Marticorena et al., 1997; Vautard et al., 2005). For some agricultural areas in Europe this factor was established at the level of 0.00× (Warren, 2000).

Within the used modelling approach, the calculated PM_{10} emission presents mainly the emission of abrasion product, excluding deflation. This approach leads to the more or less correct estimation of the PM_{10} emission from abrasion but the emission from deflation has been practically neglected.

Based on the comparison of the simulation results and results of the Dutch inventory the values were recalculated.

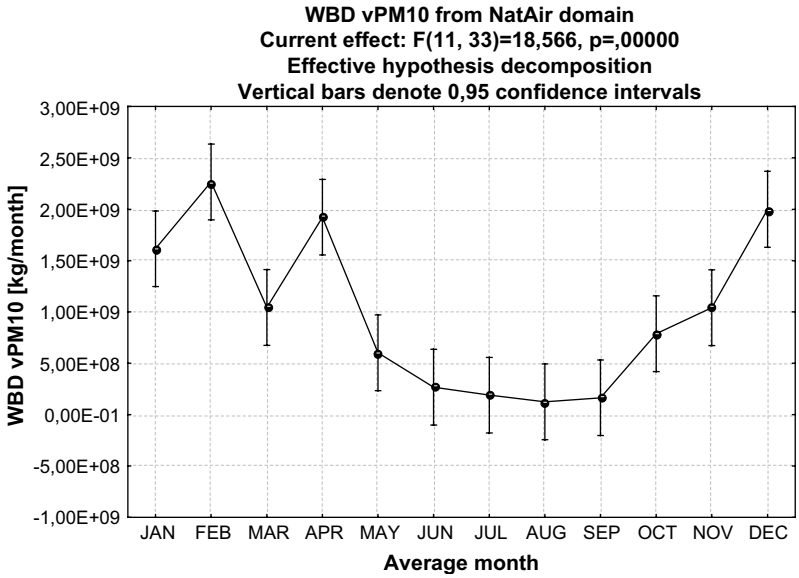


Fig. 10. Seasonal variability of the monthly wind blown PM_{10} emission factor.

This adjustment was a second meaningful source of the total uncertainty.

Statistical analysis of the monthly PM_{10} loads (for the maximum estimation) shows high variability of the PM_{10} emission during the average year, from low values (50 Gg) up to more than 2000 Gg. This variability (two orders) proves the importance of the meteorological conditions that enable the emission processes (Fig. 10).

The same conclusion results from the comparison of data calculated for the average month of the investigated year. The maximum is about 1.5 times higher than the minimum, but within the same order (Fig. 11). Taking into account that the year 2003 represents the scenario with more favourable conditions for dusting only for part of the investigated area, it should be concluded that larger differences can be expected in the wind blown PM_{10} emission than it can be observed in the simulations. Thus, the role of the wind blown dust emission in the future may increase in comparison with the present situation.

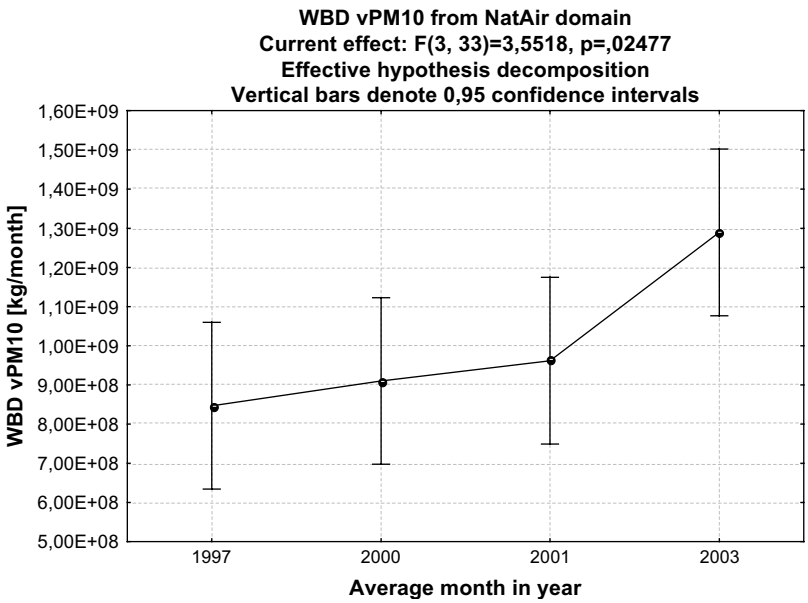


Fig. 11. Variability of the average monthly wind blown PM_{10} emission factor in successive years.

5. Conclusions and outlook

Taking the above-mentioned into account it is clear that the process of mineral dust emission has been addressed only partially. The current state of knowledge allows to determine the spatial pattern of the PM_{10} dust sources. It also allows to trace a relative importance of the sources. Locally, the state of the dust emission model development allows to simulate the wind blown PM_{10} emission with the uncertainty of about 50% (Van Harmelen et al., 2004). The mesoscale models allow to recognize this problem with higher uncertainty, which has to be decreased in the future model developments.

The wind blown dust emission is a spatially and temporarily uncontinuous process, so statistically derived factors should be treated only as a kind of guidance in outlining the PM_{10} emission inventory problem.

Further work is needed to verify the value of the ALPHA factor, which is responsible for the conversion of the horizontal emission into a vertical one. This will be possible by applying soil maps of a better spatial resolution. In the mesoscale models the final value of the PM_{10} emission should be estimated based on the adjustment of the modelled emission to the PM_{10} concentrations. It is postulated that the spatial and temporal pattern of the differences between the modelled and adjusted PM_{10} emission values should be investigated. An improvement of the erosion and resuspension models is needed for a better differentiation of the natural and anthropogenic emission within the broad group of wind blown dust emission.

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