

**23rd International Conference on
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EXTENDED ABSTRACT

Subtracting Natural Dust from PM₁₀ Concentrations in Slovakia During 2024

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Abstract

We propose four methods to estimate the contribution of natural dust to measured PM₁₀ concentrations, tested during the Saharan dust episode in Slovakia in 2024. The first method estimates natural dust contributions by de-biasing CAMS forecast dust data using CAMS forecast PM₁₀ data alongside observed PM₁₀ measurements. The second method compares measured PM₁₀ concentrations during dust episodes with concentrations on surrounding days when no dust was present. The remaining two methods are based on analyzing changes in the PM_{2.5}/PM₁₀ concentration ratio during dust events. After testing these methods over the entire year, we found that none of them is suitable to be used independently. Therefore, we propose a unified method for estimating the contribution of natural dust to measured PM₁₀ concentrations. This method is inspired by the four approaches tested during the 2024 Saharan dust episode in Slovakia and applies different techniques depending on specific conditions to determine the resulting dust contribution. The results were reported in the Annual Report on Air Quality in Slovakia 2024 and in the G Report 2024 submitted to the European Commission.

Comparison of Four Methods for Estimation of Natural Dust in measured PM₁₀ Concentrations in Slovakia during the Saharan Dust Episode 2024

We developed four different methods to estimate the contribution of natural dust to measured PM₁₀ concentrations by testing them on a Saharan dust episode in Slovakia, which lasted from March 30 to April 1, 2024. This episode represents one of the largest Saharan dust intrusions ever recorded over Slovakia. The methods rely solely on the CAMS model, specifically the CAMS ensemble DUST product, and on air quality PM₁₀ and PM_{2.5} measurements, since no other data (such as detailed PM₁₀ composition analyses) are available at the necessary quality and quantity for Slovakia.

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The first method (*Method1*) relies primarily on the CAMS forecast ensemble median DUST (*Dust CAMS*) and PM₁₀ (*PM₁₀ CAMS*) products. The contribution of natural dust to measured PM₁₀ is then estimated by bias-correcting *Dust CAMS* using actual *PM₁₀ measured* data as

$$\text{Dust in PM}_{10} (\text{Method1}) = \text{Dust CAMS} * \frac{\text{PM}_{10} \text{ measured}}{\text{PM}_{10} \text{ CAMS}}. \quad (1)$$

We also tested other CAMS outputs, including the analysis product and selected individual models, but the forecast ensemble median proved most suitable for this purpose.

The second method (*Method2*) is based on the measured daily mean PM₁₀ concentrations. First, we identified 10 non-dust days—five before and five after the Saharan dust event—using the CAMS DUST product. We defined a non-dust day as one where the 90th percentile of daily DUST values from all grid cells covering Slovakia was below 1 µg/m³, thereby indicating negligible Saharan dust influence. For those 10 days, we calculated the daily mean concentration and standard deviation at each monitoring station. The Saharan dust contribution for any given station on a given day during the episode is then determined by subtracting the non-dust daily mean from the measured concentration for that day. The method's uncertainty is represented by the standard deviation calculated over the 10 baseline days.

The third method (*Method3*) is based on the ratio $R = \text{PM}_{2.5}/\text{PM}_{10}$ calculated from measured daily averages of PM_{2.5} and PM₁₀. Two key limits of the ratio must be defined. The lower limit approximates a theoretical case in which 100% of the PM₁₀ or PM_{2.5} fraction is natural dust. This constant threshold is referred to as the dust ratio, denoted $R_D=0.19$ (Rodríguez and López-Darias, 2024). The upper limit represents a theoretical scenario in which 0% of PM₁₀ or PM_{2.5} is natural dust. Unlike the fixed lower limit, the upper limit is station-specific and season-dependent. It is calculated separately for each monitoring station and for each half of the year (warm and cold). To determine this upper limit, we use the CAMS DUST product (median analysis) to identify days with low natural dust levels in the given half-year. Specifically, only days when the daily DUST concentration is less than or equal to the 25th percentile of all days in the half-year are selected. For these low-dust days, we calculate the median of daily R values at each station. This value is referred to as R_N (non-dust ratio). Since the ratio R is highly sensitive and may vary considerably, we improve robustness by using the median R across all stations for a given day, denoted R_{all_median} . The dust ratio (DR) for a specific station and day is then calculated as

$$DR = \frac{R_N - R_{all_median}}{R_N - R_D}. \quad (2)$$

The estimated contribution of natural dust to PM₁₀ is then given by

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$$\text{Dust in } PM_{10} (\text{Method3}) = DR * PM_{10} \text{ measured} . \quad (3)$$

Finally, *Method4* is based on the hourly measured ratio $R = PM_{2.5} / PM_{10}$. A Saharan dust episode is defined when this hourly ratio falls below the station-specific 25th percentile of annual values for each monitoring site. To estimate non-dust background concentrations, we used data from days outside the episode period, specifically from March 20 to April 6, 2024. The natural dust contribution for each episode day was then calculated as the difference between the measured concentration and the non-dust background concentration.

As mentioned above, the proposed methods were tested on a Saharan dust episode in Slovakia that lasted from March 30 to April 1, 2024. Figure 1 compares the natural dust concentration estimates produced by the four methods at the air quality monitoring stations. For most stations, the estimates from the methods converge closely. In general, *Method2* yields the highest estimates of contributions, while the ratio-based methods (*Method3* and *Method4*) produce lower values.

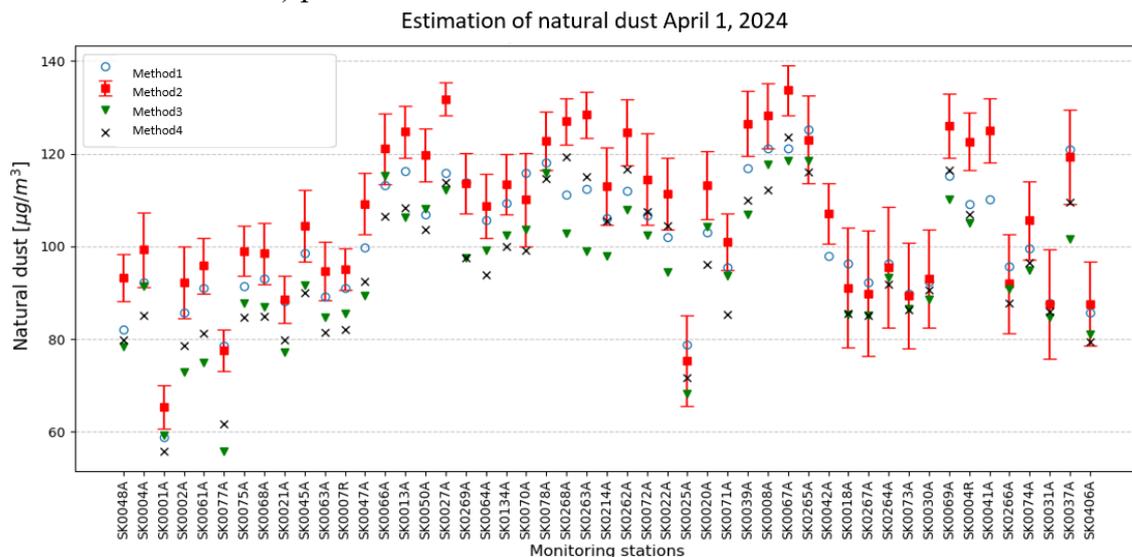


Figure 1.: Comparison of natural DUST obtained by different methods; Method1 – de-biased CAMS forecast; Method2 – based on daily mean measurement before and after episode; Method3 – based on ratio of daily mean $PM_{2.5}/PM_{10}$; Method4 – based on hourly mean $PM_{2.5}/PM_{10}$ ratio.

Estimation of Natural Dust in Measured PM_{10} Concentrations for 2024 in Annual Report on Air Quality in Slovakia

The four methods introduced in the previous chapter were tested using a Saharan dust episode in Slovakia characterized by exceptionally high natural dust levels. The EU legislation (Directive 2008/50/EC) allows subtraction of the contributions from natural sources, such as Saharan dust, when evaluating compliance with PM_{10} limit values. Therefore, we aimed to estimate the daily contribution of natural dust for each day in

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2024, and reported the resulting adjustments to measured concentrations in the Annual Report on Air Quality in Slovakia (SHMÚ, 2025). We found that no single method from our four proposed approaches could reliably estimate natural dust contributions across all conditions throughout the year. Consequently, we adopted a hybrid strategy, dynamically combining methods based on contextual suitability to achieve more reliable results. The methodology is described in (Hrabčák and Štefánik, 2025).

In 2024, a total of 107 days with potential natural dust occurrence were found. Of these, 2 days were linked to the Arabian Peninsula region, and 9 days to the arid areas around the Caspian Sea. A record number of days—96 in total—were identified with potential Sahara dust occurrence, which is the highest number observed since at least 2015 (Hrabčák, 2022). The year 2024 brought an exceptional episode of Saharan dust transport, peaking on April 1. In Table 1 we present the number of days with PM₁₀ daily limit exceedances recorded at air quality stations of the National Air Quality Monitoring Network in Slovakia in 2024, along with the exceedances remaining after subtraction of natural dust contributions. The table shows that subtraction of natural dust episodes leads to a decrease in exceedance counts at all stations, mostly by 1 to 3 days. The highest reduction in exceedances was observed at Veľká Ida, where exceedances decreased from 46 to 39 days. Although the number of exceedance days was reduced, stations that initially exceeded the EU limit of 35 days per year remain above this threshold even after subtraction of natural dust. This applies to stations such as Jelšava, Plášťovce, and Veľká Ida.

Table 1. Summarized number of exceedances (mean daily PM₁₀ concentrations > 50 µg/m³) before and after subtraction of natural dust daily mean.

Eol	AMS	Exceedances	Exceedances after dust subtraction	Eol	AMS	Exceedances	Exceedances after dust subtraction
SK0048A	Bratislava, Jeséniova	7	4	SK0025A	Jelšava, Jesenského	53	48
SK0004A	Bratislava, Kamenné nám	6	3	SK0072A	Lučenec, Gemerská cesta	22	19
SK0001A	Bratislava, Mamateyova	3	2	SK0262A	Zvolen, J. Alexyho	5	2
SK0061A	Bratislava, Púchovská	13	10	SK0078A	Žarnovica	24	21
SK0002A	Bratislava, Trnavské mýto	12	9	SK0268A	Žiar nad Hronom, Jilemnického	3	0
SK0075A	Pezinok, Obrancov mieru	7	4	SK0067A	Liptovský Mikuláš, Školská	9	6
SK0077A	Rohožník, Senická	7	4	SK0039A	Martin, Jesenského	16	13
SK0076A	Rovinka	4	1	SK0071A	Oščadnica	12	9
SK0068A	Senec, Boldocká	8	5	SK0008A	Ružomberok, Riadok	16	13
SK0021A	Senica, Hviezdoslavova	6	3	SK0020A	Žilina, Obežná	17	12
SK0063A	Sereď, Vinárska	7	5	SK0074A	Bardejov, Pod Vinbargom	1	0
SK0007R	Topoľníky, Aszód, EMEP	7	5	SK0041A	Gánovce, Meteo. st.	3	0
SK0045A	Trnava, Kollárova	6	3	SK0037A	Humenné, Nám. Slobody	5	3
SK0064A	Komárno, Vnútoraná Okružná	11	7	SK0406A	Kolonické sedlo	2	1

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Eol	AMS	Exceedances	Exceedances after dust subtraction	Eol	AMS	Exceedances	Exceedances after dust subtraction
SK0134A	Nitra, Janíkovce	6	3	SK0069A	Poprad, Železničná	3	0
SK0269A	Nitra, Štúrova	9	6	SK0266A	Prešov, Arm. gen. L. Svobodu	15	14
SK0070A	Plášťovce	43	39	SK0004R	Stará Lesná, AÚ SAV, EMEP	3	0
SK0013A	Bystričany, Rozvodňa SSE	7	4	SK0031A	Vranov nad Topľou, M. R. Štefánika	3	2
SK0027A	Handlová, Morovnianska cesta	6	3	SK0264A	Košice, Amurská	12	11
SK0050A	Prievidza, Malonecpalská	7	4	SK0267A	Košice, Štefánikova	21	18
SK0066A	Púchov, 1. mája	12	8	SK0018A	Veľká Ida, Letná	46	39
SK0047A	Trenčín, Hasičská	15	12	SK0042A	Kojšovská hoľa	1	0
SK0214A	Banská Bystrica, Štefánikovo nábr.	22	16	SK0265A	Krompachy, SNP	13	10
SK0263A	Banská Bystrica, Zelená	4	1	SK0030A	Strážske, Mierová	3	2
SK0022A	Hnúšťa, Hlavná	8	5	SK0073A	Trebišov, T. G. Masaryka	10	7

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