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Subtracting Natural Dust from PM_{10} Concentrations in Slovakia during 2024

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Abstract

We tested four methods to estimate natural dust contributions to PM_{10} concentrations during the 2024 Saharan dust episode in Slovakia. The first approach corrected CAMS dust forecasts using CAMS PM_{10} and observed PM_{10} data. The second compared PM_{10} during dust events with nearby dust-free days. The remaining two analyzed changes in the $PM_{2.5}/PM_{10}$ ratio. None of the methods proved reliable on their own, so we propose a unified approach combining elements of primary methods, applying different techniques depending on conditions. Results were included in the 2024 Slovak Air Quality Annual Report and the G Report submitted to the European Commission.

Comparison of Four Methods for Estimation of Natural Dust in measured PM_{10} Concentrations in Slovakia during the Easter Saharan Dust Episode 2024

Four approaches were tested to estimate natural dust contributions to PM_{10} during the Easter Saharan dust episode (March 30 – April 1, 2024) in Slovakia.

Data sources:

- CAMS ensemble DUST and PM_{10} products
- Observed PM_{10} & $PM_{2.5}$
- No chemical composition data available

Method_1 – Bias Correction

- Uses CAMS forecast ensemble median DUST & PM_{10}
- Natural dust contribution = bias-corrected CAMS DUST using observed PM_{10}
- Forecast ensemble median found most suitable (better than analyzes)

Method_2 – Non-Dust Baseline Comparison

- Identify 10 non-dust days (5 before & 5 after event) using CAMS DUST (<1 µg/m³ at 90th percentile)
- Compute daily mean & SD at each station for these days
- Dust contribution = measured PM_{10} – baseline mean

Method_3 – Daily $PM_{2.5}/PM_{10}$ Ratio

- Compute daily ratio $R = PM_{2.5}/PM_{10}$
- Define thresholds:
  - Lower limit (RD = 0.19) → 100% dust (assume: Rodríguez & López-Darias, 2024)
  - Upper limit (RN) → no dust, station & season-specific
- RN from low-dust days (≤ 25th percentile CAMS DUST)
- Dust ratio: $DR = (RN - R_{all\_median})/(RN - RD)$
- Contribution = DR × PM_{10} measured

Method_4 – Hourly Ratio Analysis

- Hourly ratio $R = PM_{2.5} / PM_{10}$
- Dust episode when R < station-specific 25th percentile
- Background = non-episode days (Mar 20–Apr 6)
- Dust contribution = measured – background

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, *Method_2* yields the highest estimates of contributions, while the ratio-based methods (*Method_3* and *Method_4*) produce lower values.

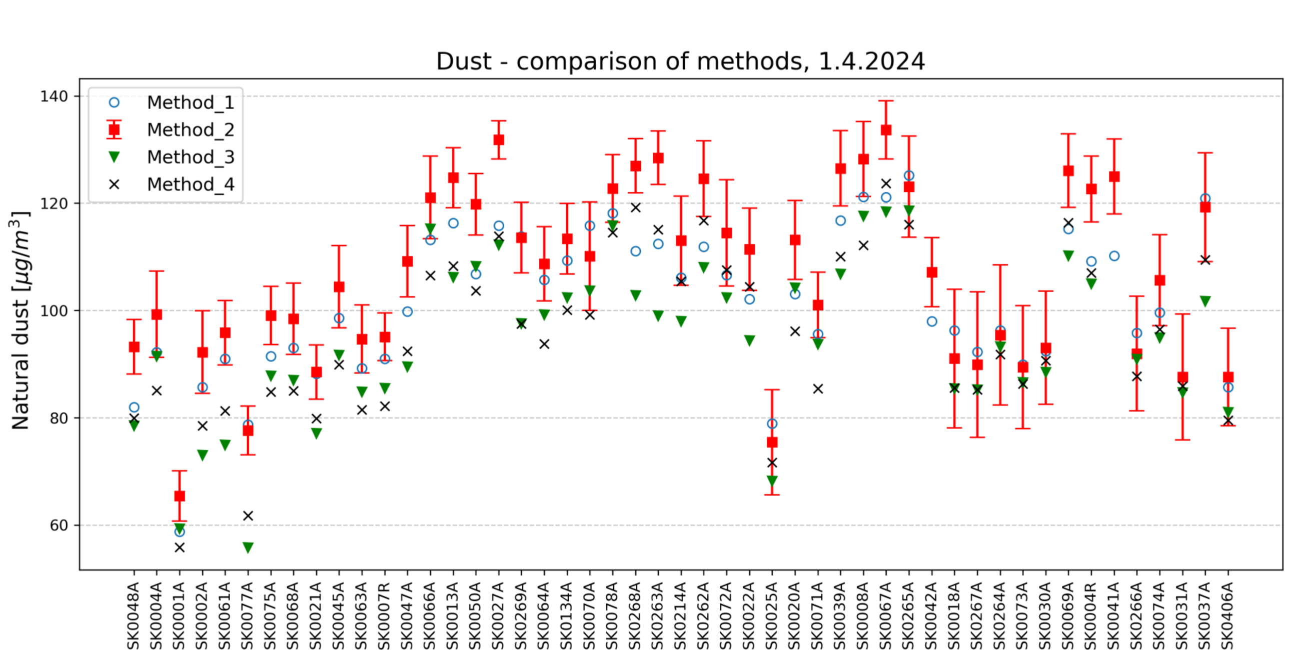

Fig. 1 *Comparison of natural DUST obtained by different methods; Method_1 – de-biased CAMS forecast; Method_2 – based on daily mean measurement before and after episode; Method_3 – based on ratio of daily mean $PM_{2.5}/PM_{10}$; Method_4 – based on hourly mean $PM_{2.5}$ / PM_{10} ratio.*

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 the Easter 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 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 approaches 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 PM_{10} 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 PM_{10} concentrations > 50 µg/m³) before and after subtraction of natural dust daily mean.*

EoI	AMS	Exceedances	Exceedances after dust subtraction	EoI	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, Vnútorná Okružná	11	7	SK0406A	Kolonické sedlo	2	1
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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