**Supplement: Contribution of black carbon and desert dust to aerosol absorption in the atmosphere of the Eastern Arabian Peninsula**

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# LIST OF ABBREVIATIONS

|  |  |
| --- | --- |
| a.s.l | Above sea level |
| AAE | Absorption Ångström Exponent |
| AE | Aethalometer – filter-based absorption photometer |
| AE33 | Aethalometer AE33 |
| AG | Arabian Gulf |
| AP | Arabian Peninsula |
| ATN | Attenuation |
| BB | Biomass burning |
| BC | Black carbon |
| BC (ATN) | BC as a function of the measured attenuation |
| BrC | Brown carbon |
| CE | Concentration enhancement factor |
| DS | Dust storm period |
| EF | Enhancement factor |
| GDAS | Global Data Assimilation System |
| GUI | Graphical User Interface |
| HiVol | High volume sampler |
| HIM | Helium Ion Microscopy |
| HYSPLIT | Hybrid Single Lagrangian Integrate Trajectory |
| IPCC | Intergovernmental Panel on Climate Change |
| MAC | Mass absorption cross section |
| Non-DS | Non dust storm period |
| NWR | Non-parametric wind regression |
| OPS | Optical particle sizer |
| PAS | Photoacoustic photometer |
| PM1 | Particulate matter with aerodynamic diameter < 1 µm |
| PM10 | Particulate matter with aerodynamic diameter < 10 um |
| PNC | Particle number concentration |
| PSCF | Potential source contribution function |
| PSAP | Particle Soot Absorption Photometer |
| QU | Urban background site |
| RM | Regional background site |
| SAE | Scattering Ångström exponent |
| SSA | Single Scattering Albedo |

**Virtual impactor**

Figure S1 illustrates the VI design where the aerosol sample passes through an accelerating nozzle and is directed toward a collection probe (Drinovec et al., 2020). At this point, a major portion of the flow is diverted 90° away from the collection probe where the particle-size separation takes place. Due to inertia, the supermicron particles portion deviates from the flow lines and continues to move axially on its forward path down the collection probe with a minor flow. Similarly to what was reported by Sioutas et al., (1994), the VI sampling of ambient air as total suspended particulate (TSP) occurred at a total flow rate of 100 LPM. The major flow (Fin = 98 LPM) in the VI is directed to the pump. Supermicron particles are segregated and concentrated into the minor flow (Fout=2 LPM) directed to AE33. However, the aerosol submicron fraction (PM1) concentration is the same in the major and minor VI flows and equals the ambient concentrations. The concentration efficiency (CE) defines the enhancement ratio of the supermicron fraction relative to the ambient concentrations.

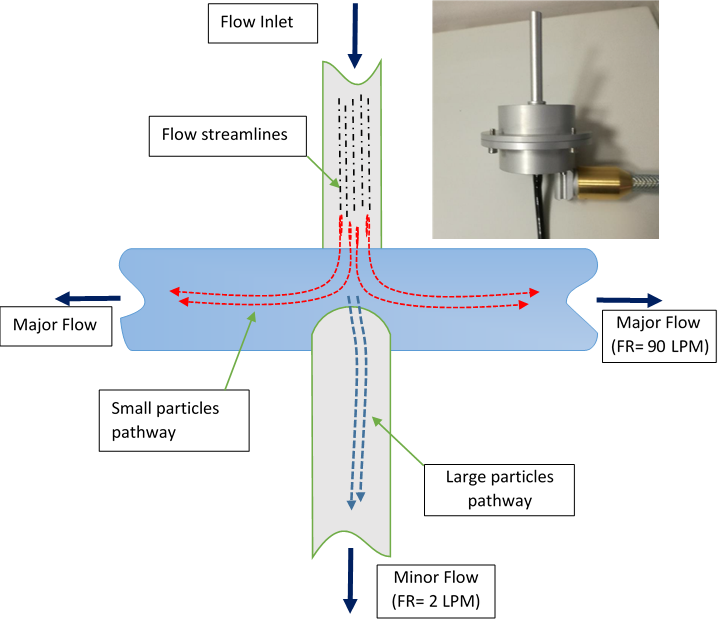


Figure S1: VI schematic diagram showing the trajectories of the submicron (red dashed lines) and supermicron fractions (blue dashed lines). Major and minor flow rate (FR) are described for 90 and 2 LPM respectively.

The enhancement factor (EF) is the main characteristic of any virtual impactor. The EF is calculated from the ratio of the integral volume size distribution of the particles in the VI minor flow (VVI) relative to the integral volume size distribution of the ambient particles (V) (Drinovec et al., 2020):

(1)

where and , is the particle aerodynamic diameter and CE is the collection efficiency calculated as for particle number concentration with the VI and ambient particle number concentration.

**Wind speed diurnal profile**

Average wind speed exhibits elevated values during DS compared to the NonDS periods, as indicated in Figure S2. The dust and BC at the RB site come from a consistent direction. Given the considerable distance between the source and the receptor at the RM site, receiving these pollutants requires strong winds that occur only during the period and influenced the receptor site. This may explain the diurnal variation at the measurement site.

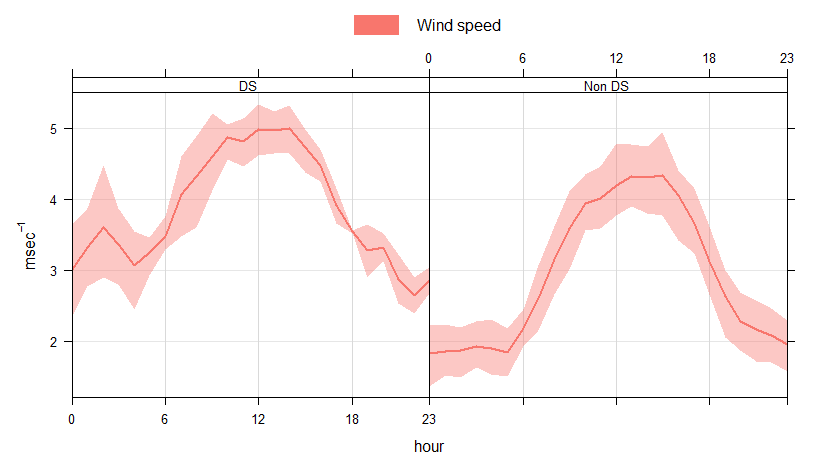


Figure S2: Wind speed diurnal variation during DS and NonDS periods measured at the UB site

**Non-parametric wind regression**

The investigation of the geographical origins of atmospheric pollutants based on wind data and backward trajectory have been used widely in many apportionment studies. We used the ZeFir toolkit in order to allocate the potential local/regional source(s) in addition to the routes of the transported air mass to the monitored sites. ZeFir is a user-friendly graphical user interface (GUI) tool developed by Petit et al., (2015) to operate with Igor Pro 6.0 (from WaveMatrices Inc). ZeFir has two main modules for analysis: wind regression and trajectory analysis.

The wind analysis was performed using the non-parametric wind regression (NWR) method first described by (Henry et al., 2009). The NWR method can, under appropriate assumptions, apportion source regions of a pollutant to multiple sources without the use of chemical fingerprints or emissions inventories. The basic principal of NWR is the calculation (prediction) of the pollutant value as a function of the wind direction (𝜃) and speed (u), as a weighted average smoothed by the parameters of σ and h. Weighing of the pollutant values is calculated with the kernel function K (θ, u, σ, h) = (θ,σ) (u,h). The expected value C given wind direction θ and speed u is estimated by:

(2)

where, , , and are the observed concentration of a particular pollutant, the resultant wind speed and direction, respectively, for the  th observation in a time period starting at time ; N is the total number of observations.

Two well-known kernel functions are the (for wind direction) Gaussian kernel given by,

, -∞ < x < ∞ (3)

and the (for wind speed) Epanechnikov kernel,

, -1 < x < 1 = 0, otherwise. (4)

The fact that the values of and calculated by ZeFir and the smoothing parameters σ and h are user definable means that it could give the best plotting results and highest resolution recognising source(s) locations.

**Potential Source Contribution Function (PSCF)**

PSCF is mainly based on coupling air pollutant concentrations data and air mass history for the investigation of potentially advected pollution over large geographical areas. It specifically investigates the probability of an air parcel being responsible for measured concentrations at the receptor site above a user-defined threshold. This threshold is a percentile value (75th or 90th ; Petit et al., 2015):

(5)

where is the total count of trajectory endpoints in the cell, and the count of trajectory endpoints in the cell associated with concentrations above the defined threshold.

**Clustering analysis**

An air mass analysis built on 48h back trajectories arriving at the UB site located at 100 m above sea level for the period of the monitoring, including dust storms. The analysis first calculated for each hour interval and then grouped into five main groups. Cluster analysis and the selection of the optimum number of clusters was based on total spatial variance (TSV) (Figures S3 and S4). Cluster number 4 originating from the NW features a high dust-related absorption coefficient, while BC-dominated absorption exhibits high values for clusters numbers 2 and 5, which also correspond to air arriving from the NW direction but originating from different locations either closer or farther away from the monitored sites. For example, cluster number 2 originates over south-east Iraq crossing the waters, indicating a lower wind speed, while clusters number 4 and 5 originate farther away in the northwest of Syria and Iraq, indicating higher wind speeds. The difference in the dust and BC back-trajectory clusters indicates potential local source locations for BC-dominated aerosol.

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| Figure S3: Optimum cluster number for absorption coefficient (A) TSV change, (B) absorption coefficient at 370 nm exerted by the supermicron fraction (C) at 370 nm exerted by the submicron fraction |

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| Figure S4: (A) Five selected clusters, the corresponding absorption coefficients (Mm-1); (B) the supermicron fraction (370 nm); (C) the submicron fraction (950 nm) at the urban site |

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