Evidence of a Saharan dust event from air quality measurements in UK schools within the SAMHE project

Sam Wood & the SAMHE team

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1 Introduction

Saharan dust events occur in the UK when strong winds over the Sahara desert lift sand and dust into the upper atmosphere and carry it north, resulting in higher-than-usual measurements for particulate matter (PM). These events can happen several times a year and are recognisable by an orange tint to the sky and particularly vivid orange sunsets. A visible layer of fine, often orange coloured, dust may also form, particularly after rainfall. Changes in rainfall patterns resulting from climate change make these events more frequent [1]. In this technical report, a Saharan dust event from early September 2023 (see the satellite images in figure 1) is investigated and its impact on air quality inside UK classrooms is evidenced by the measurements of $PM_{2.5}$ by the SAMHE monitors (see www.SAMHE.org.uk).

2 PM measurements in the September Saharan dust event

Particulate matter (PM) arises from a wide variety of indoor sources and outdoor sources, including both natural processes and human activities. Although all air will contain an amount of PM, they are an important indicator of air quality with, for example, links to increased incidences of asthma and other respiratory conditions. Young people can be particularly susceptible to health effects resulting from poor indoor air quality as they are still in their developmental stage [2]. Concentrations of some pollutants indoors are typically significantly higher than outdoors, so good ventilation can reduce their build up. However, when the outdoor pollutant concentration is very high this may not be effective [3].

Outdoor PM values are measured across the UK by the Automatic Urban and Rural Network (AURN), which provides hourly air quality data from 174

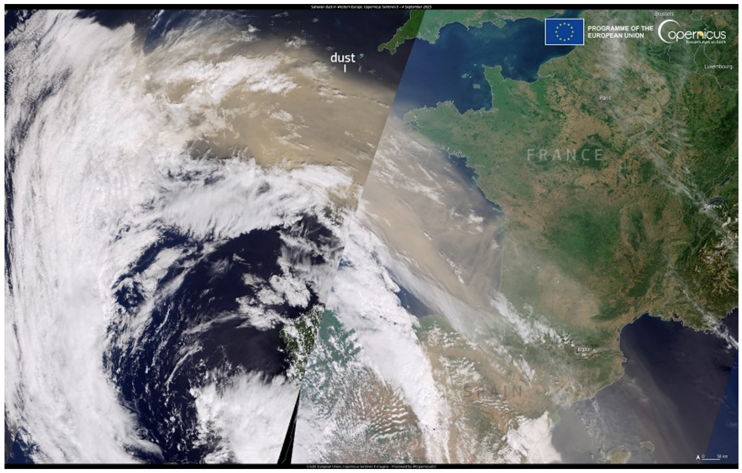

Figure 1: Satellite photography from 04/09/2023 showing a plume of Sahara dust stretching out into the Atlantic Ocean and approaching the southwest coast of England. Credit: European Union, Copernicus Sentinel-3 imagery

sites across the UK. The AURN exists to ensure statutory air quality standards are met and provide air quality data to researchers and the public.

In early September 2023, strong winds carried significant quantities of sand and dust from the Sahara to the UK, resulting in elevated outdoor PM measurements — we investigate the effects of a Saharan dust event on UK air quality, all the way through to classrooms.

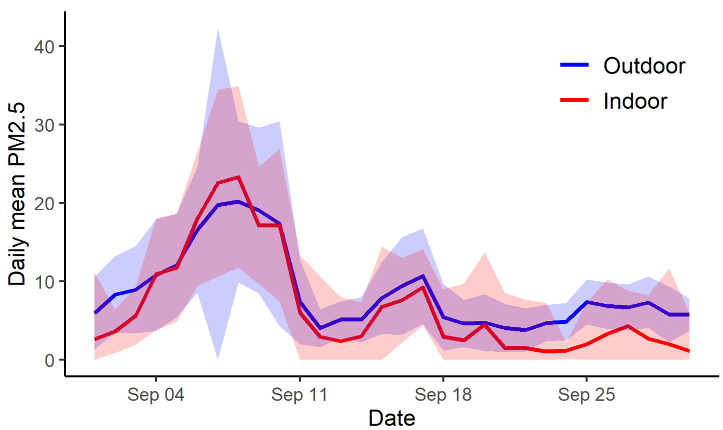

Figure 2: The daily mean $PM_{2.5}$ measurement in September 2023 measured in 202 classrooms in the SAMHE network (labelled 'Indoor'), and 102 sites in the AURN network (labelled 'Outdoor'). The shaded area represents values within one standard deviation of the daily mean.

SAMHE SCHOOLS' AIR QUALITY MONITORING FOR HEALTH AND EDUCATION

Figure 2 shows the daily mean $PM_{2.5}$ measurements, averaged across the eight hour period from 08:00 to 16:00, for September, measured both outdoors (by the AURN monitors) and inside classrooms using SAMHE monitors. Both indoor and outdoor readings are significantly higher in the first half of the month, rising to a peak on 07/Sep. A number of media reports about Sahara dust over the UK occur around this date, e.g. [4, 5]. It is noteworthy that there were days in which the mean $PM_{2.5}$ measurement across all classrooms was higher than that outdoors; this is in contrast to later in the month, when the average $PM_{2.5}$ measurements indoors were consistently lower than those outdoors. It is worth noting the possibility that indoor $PM_{2.5}$ measurements might also have been increased by other dust, that had settled in the school over the quiet summer period, being re-suspended by increased activities at the start of term (during the week commencing 4/Sep in England and Wales) — although the strong correlation with outdoor $PM_{2.5}$ measurements during this period indicates the start of term did not have a dominant effect.

The standard deviation of mean daily outdoor $PM_{2.5}$, illustrated by the shading in Figure 2, is large during this Sahara dust event, suggesting a high variation between PMs measured at sites across the UK. Figure 3 shows the measured outdoor PMs across all functioning AURN sites on the peak day (07/Sep), and on 09/Sep and 11/Sep. There is clear variation in the PM levels measured across the nation over the course of this event. A geographic variation in $PM_{2.5}$ is to be expected even under normal conditions — typically PM levels will be higher in cities than in rural areas, for example, and a number of other local factors will also have an effect too. Examination of the outdoor $PM_{2.5}$ measurements on 07/Sep and 09/Sep indicates high values and wide variation in PM levels throughout the country; in contrast, the outdoor $PM_{2.5}$ levels on 11/Sep (when the Sahara dust had largely passed the UK) are significantly lower and show less variation. This suggests that the higher outdoor PMs, observed in most regions, are at least partially due to the presence of Saharan dust, and that distribution of Sahara dust around the UK is uneven.

We now compare the classroom $PM_{2.5}$ measurement made indoors for SAMHE schools to the outdoor $PM_{2.5}$ measurements made local to each school. Such a comparison is not valid for all SAMHE schools, as many (particularly rural) schools are too far from AURN stations to gather representative outdoor measurements. The mean $PM_{2.5}$ averaged over two separate three day periods, the first (06/Sep–08/Sep) including the peak of the Sahara dust event and the second (20/Sep–22/Sep) being representative of more typical conditions, is shown in Figure 4. Both of these periods cover the days Wednesday to Friday, to account for any weekday bias in outdoor $PM_{2.5}$ measurements; for example, arising from working and commuting patterns. Only those 42 schools which are within 2km of a working AURN site are included.

It is clear from Figure 4 that indoor PM levels were consistently higher during the Saharan dust event than under normal conditions. However, there is significant variation in the extent to which indoor $PM_{2.5}$ for a given school reflects outdoor $PM_{2.5}$. This may be due to a number of factors including the distance between the AURN site and the classroom, but is likely to be strongly

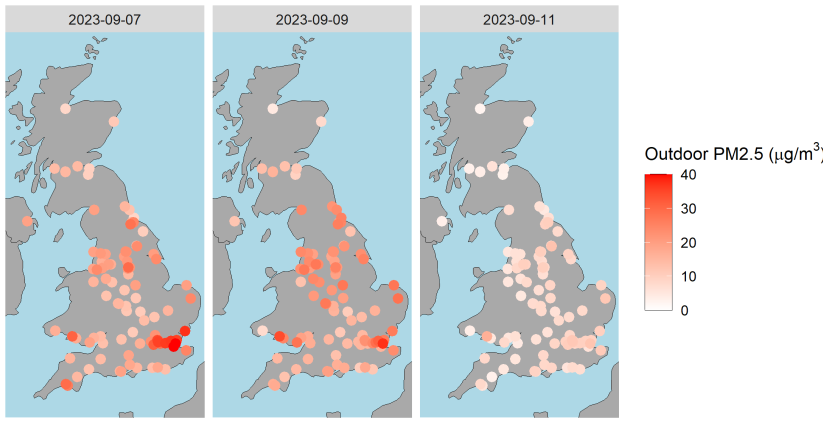

Figure 3: The daily averaged outdoor $PM_{2.5}$ levels measured at the functioning AURN sites at selected dates (07/Sep, 09/Sep, and 11/Sep) including peak of the Sahara dust event over the UK.

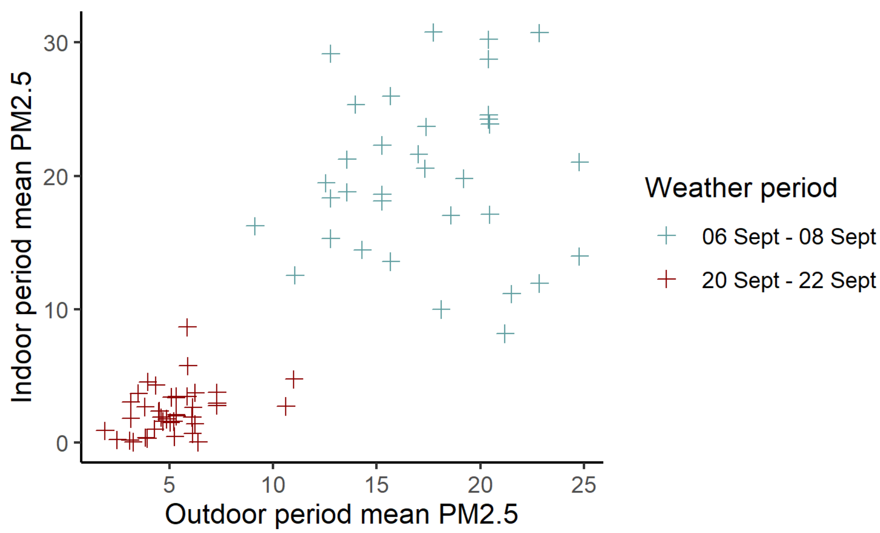

Figure 4: The indoor mean $PM_{2.5}$ measurement for the period 06 Sep - 08 Sep (the peak period of Sahara dust over the UK) compared to the period 20 Sep - 22 Sep (representative of more typical conditions), and a best-fit line for each group based on simple linear regression.

influenced by the nature of the ventilation at the school.

3 Conclusions

The effect on air quality in UK schools of Saharan dust, carried across Europe by a storm, was investigated using SAMHE monitors and monitors from the Automatic Urban and Rural Network (AURN). A significant rise in both indoor and outdoor $PM_{2.5}$ measurements was seen during the period that Saharan dust was reported to be over the UK. Greater regional variation in outdoor $PM_{2.5}$ measurements was seen during this period than after, suggesting some regions were more strongly affected than others.

Although almost all schools showed increased $PM_{2.5}$ levels indoors during this dust event, there was a large variation in the extent to which increased outdoor PMs were reflected in indoor measurements. An improved understanding of the factors that caused some schools to be heavily affected by high outdoor PMs while others were not may help develop practices to keep good air quality indoors, even in environments where the outdoor air quality is poor.

Acknowledgements

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References

[1] Josh Marcus. Is the climate crisis impacting sahara dust storms? *The Independent*, 2023.

[2] Fiona C Goldizen, Peter D Sly, and Luke D Knibbs. Respiratory effects of air pollution on children. *Pediatric pulmonology*, 51(1):94–108, 2016.

[3] Lance A Wallace, Edo D Pellizzari, Tyler D Hartwell, Roy Whitmore, Charles Sparacino, and Harvey Zelon. Total exposure assessment methodology (team) study: personal exposures, indoor-outdoor relationships, and breath levels of volatile organic compounds in new jersey. *Environment International*, 12(1-4):369–387, 1986.

[4] Maryam Zakir-Hussain. Sahara dust cloud sweeps uk as experts issue warning. *The Independent*, 2023.

[5] Benedict Tetzlaff-Deas. Everything you need to know about saharan dust cloud as air pollution strikes uk. *mirror.co.uk*, 2023.