Air Quality Consultants

Air Quality Monitoring Report:
Domestic Solid-Fuel Burning Grant Funded Project

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Experts in air quality
management & assessment

Document Control

Client	North West Leicestershire District Council and Harborough Council	Principal Contact	Minna Scott (NWLDC)

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Report Prepared By:	Suzanne Hodgson, Dr Kate Wilkins and Dr Clare Beattie

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Air Quality Consultants Ltd
23 Coldharbour Road, Bristol BS6 7JT Tel: 0117 974 1086
24 Greville Street, Farringdon, London, EC1N 8SS Tel: 020 3873 4780
aqc@aqconsultants.co.uk

Registered Office: 23 Coldharbour Road, Bristol BS6 7JT
Companies House Registration No: 2814570

Contents

1 Introduction

1.1 Poor air quality is one of the greatest environmental risks to public health in the UK. Long term exposure to air pollution can cause chronic conditions such as cardiovascular and respiratory diseases as well as lung cancer, leading to reduced life expectancy. Short term exposure (over hours or days) to elevated levels of air pollution can also cause a range of health effects related to lung function, exacerbation of asthma, increases in respiratory and cardiovascular hospital admissions, and mortality. There are a number of other emerging links for air pollution and health, including dementia, a variety of mental health conditions, and adverse pregnancy outcomes.

1.2 This report provides the results and analysis of a 12-month $PM_{2.5}$ monitoring programme carried out at three sites in the administrative areas covered by North West Leicestershire (NWL) and Harborough District Council's, as part of a Defra grant funded project investigating domestic solid fuel burning. The key objective of the project was to reduce $PM_{2.5}$ emissions by increasing awareness of, and changing attitudes to, solid fuel burning, resulting in behaviour change. Changes could include a reduction in burning or use of fuels which have lower emissions (for example, dry wood has lower emissions than unseasoned wood). To support the project, 12-months of air quality monitoring was undertaken at three sites which were thought to represent areas with high levels of domestic solid fuel burning, in order to provide a better understanding of current concentrations, how they vary and how they relate to overall $PM_{2.5}$ emissions within the NWL and Harborough areas. AQC has been commissioned by NWL and Harborough District Council's to collate the data and provide an interpretation of the outcomes of the monitoring study.

1.3 The three sites were selected in off gas areas where there is old housing stock, using local knowledge, to best represent areas of high levels of solid fuel burning. Monitoring at the three sites was undertaken using Zephyr monitors (provided by Earthsense[1]). This report provides the results and analysis of the 12-month monitoring programme (15th September 2022 to 30th September 2023), at the three sites, to determine both the concentrations at the sites, and if measured $PM_{2.5}$ concentrations in the vicinity of each site show any influence of solid-fuel wood burning. Analysis has been undertaken based on standard statistics for comparison with air quality objectives and targets and 'openair' (Carslaw D. R., 2012) software[2] to derive a range of graphical plots. Comparison has also been made between the Zephyr data and results from nearby urban background sites within Defra's Automatic Urban and Rural Network (AURN) (Defra, 2023a).

[1] https://www.earthsense.co.uk/zephyr

2 'openair' is an R package (which is a programming language for statistical computing and graphics) developed for the purpose of analysing air quality data.

2 Context

2.1 Emissions from solid fuel burning will mainly impact on concentrations of Particulate Matter (PM), which is the term for particles found in the air, including dust, dirt, soot, smoke, and liquid droplets. PM has many different sources, both natural and anthropogenic, including solid fuel burning. In terms of the health effects, exposure to $PM_{2.5}$ (PM less than 2.5 micrometres in diameter) is the most important, although other pollutants all add to the burden of disease, to a greater or lesser extent. Current evidence suggests that there is no safe threshold for exposure to $PM_{2.5}$. For this reason, the analysis will focus on $PM_{2.5}$.

2.2 Wood burning stoves and coal fires are a major contributor nationally to emissions of particulate matter, and the Government is taking steps to tackle these emissions, largely through the Domestic Solid Fuel Regulations which have phased out sales of bagged coal and wet wood, two of the most polluting fuels. Accompanying information campaigns such as 'Burn Better' encourages solid fuel users to make positive changes to their burning habits.

Air Quality Objectives and Targets

2.3 The Government has established a set of air quality standards and objectives to protect human health. The 'standards' are set as concentrations below which effects are unlikely even in sensitive population groups, or below which risks to public health would be exceedingly small. They are based purely upon the scientific and medical evidence of the effects of an individual pollutant. The 'objectives' set out the extent to which the Government expects the standards to be achieved by a certain date. They take account of economic efficiency, practicability, technical feasibility and timescale. There is no current air quality objective in regulations for $PM_{2.5}$ for local authorities to meet, and in the absence of a numerical objective, it is convention to assess local air quality against the limit value, originally set at 25 µg/m^3 and currently set at 20 µg/m^3.

2.4 Resulting from the Environment Act (2021), which gives the Government the power to set long-term, legally binding environmental targets, Defra has set two targets, and two interim targets, for $PM_{2.5}$ concentrations in England. One set of targets focuses on absolute concentrations. The long-term target is to achieve an annual mean $PM_{2.5}$ concentration of 10 µg/m^3 by the end of 2040, with the interim target being a value of 12 µg/m^3 by the start of 2028. The second set of targets relate to reducing overall population exposure to $PM_{2.5}$. By the end of 2040, overall population exposure to $PM_{2.5}$ should be reduced by 35% compared with 2018 levels, with the interim target being a reduction of 22% by the start of 2028. Local authorities have an important role delivering the required improvements, which are expected to focus on controlling emissions.

2.5 The air quality criteria relevant for this monitoring report are provided in Table 1.

Table 1: Air Quality Objectives for PM_{10} and Target for $PM_{2.5}$

Pollutant	Time Period	Value
PM_{10}	24-hour Mean	50 µg/m³ not to be exceeded more than 35 times a year
	Annual Mean	40 µg/m³
$PM_{2.5}$	Annual Mean	20 µg/m³ [a]
		12 µg/m³ (to be achieved by 2028)
		10 µg/m³ (to be achieved by 2040)

a There is no numerical $PM_{2.5}$ objective for local authorities (see Paragraph 2.3). Convention is to assess against the UK limit value which is currently 20 µg/m³.

Sources and Variation in $PM_{2.5}$

2.6 $PM_{2.5}$ concentrations vary across the year. For example, a peak in early spring is typical for $PM_{2.5}$, as elevated concentrations of nitrates (a pre-curser to $PM_{2.5}$) are transported from agricultural operations across continental Europe (Air Quality Expert Group, 2012). Domestic combustion of wood and coal in stoves and open fires is a large contributor to emissions of $PM_{2.5}$ and is a contributing factor towards elevated concentrations in winter months. There are, however, also meteorological reasons why $PM_{2.5}$ may be higher in colder months. $PM_{2.5}$ includes volatile components which exist as gases when warm, only forming $PM_{2.5}$ when it turns cold. Colder air is also denser than warmer air and when the temperature drops, cold air can form a barrier to the dispersion of pollutants (Defra, 2023b). Hence comparisons with temperature may not be solely attributable to peaks in solid fuel burning.

2.7 It should be noted that there are a large number of emission sources for particulate matter, and there may be other sources which contribute to changing concentrations. There can be considerable contribution from sources originating outside of the UK. The level of transboundary derived particulates is determined by wider-scale emissions and weather conditions.

3 Monitoring Locations and Technology

Monitoring Locations

3.1 Monitoring was undertaken at three locations within the study area, the locations are listed below and shown in Figures 1a and 1b:

- Z1141 – Donisthorpe
- Z1142 – Oakthorpe
- Z1083 – North Kilworth

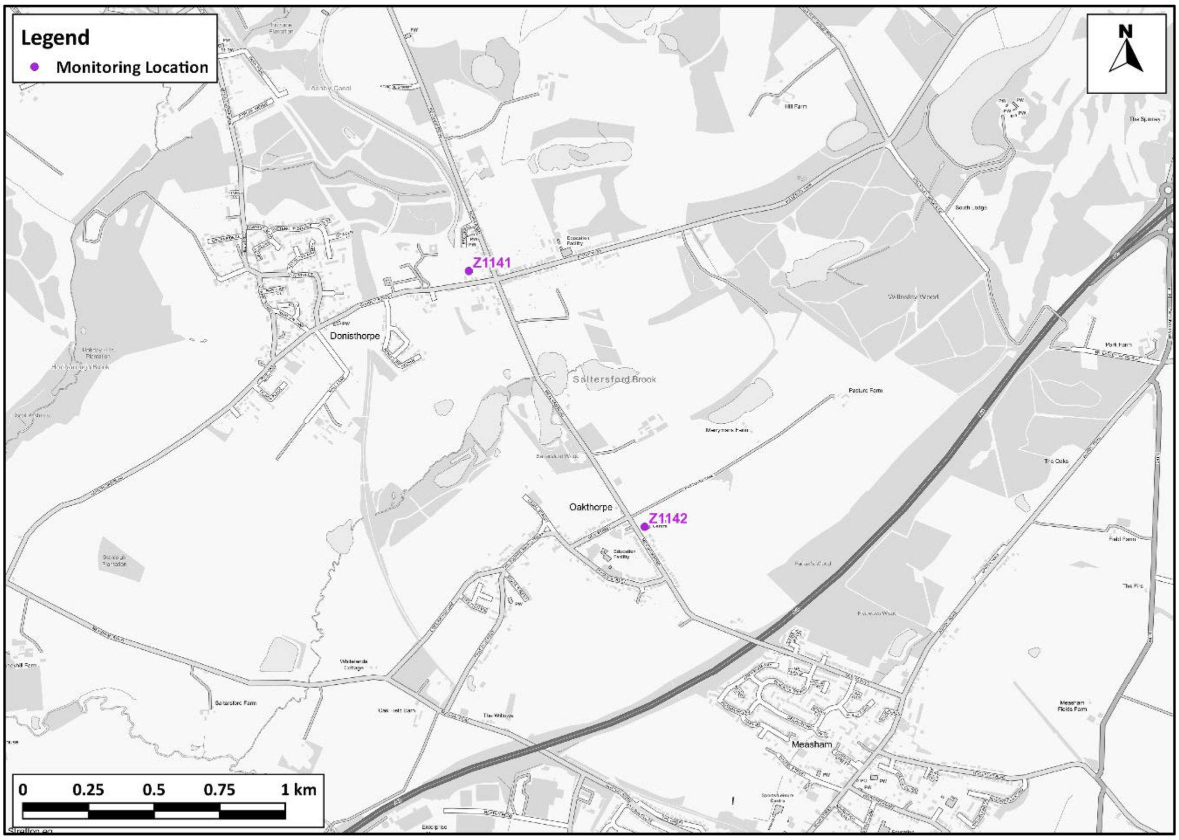


Figure 1a: Location of Z1141 (Donisthorpe) and Z1142 (Oakthorpe)

Imagery ©2023 Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies, The GeoInformation Group.

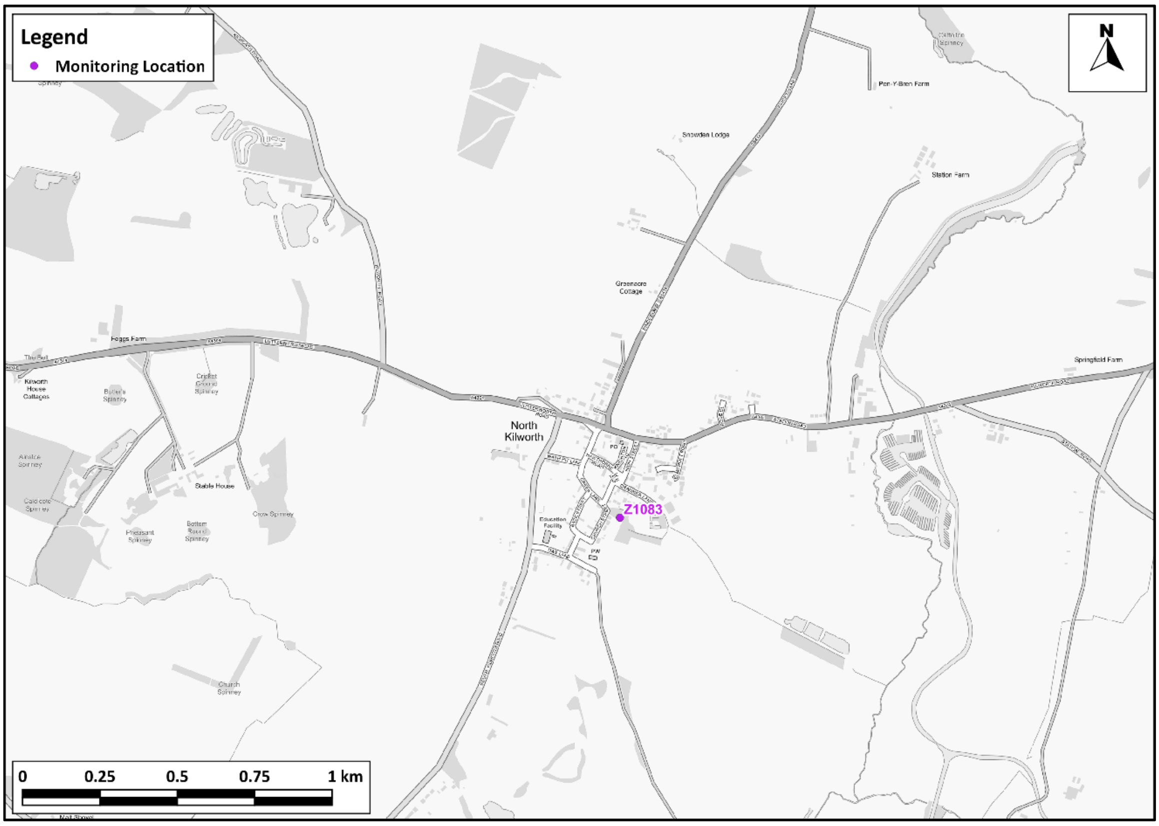


Figure 2b: Location of Z1083 (North Kilworth)

Imagery ©2023 Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies, The GeoInformation Group.

3.2 The locations of all three monitors are also shown in Figure 2; to contextualise the overall geographic location of the monitors within the districts.

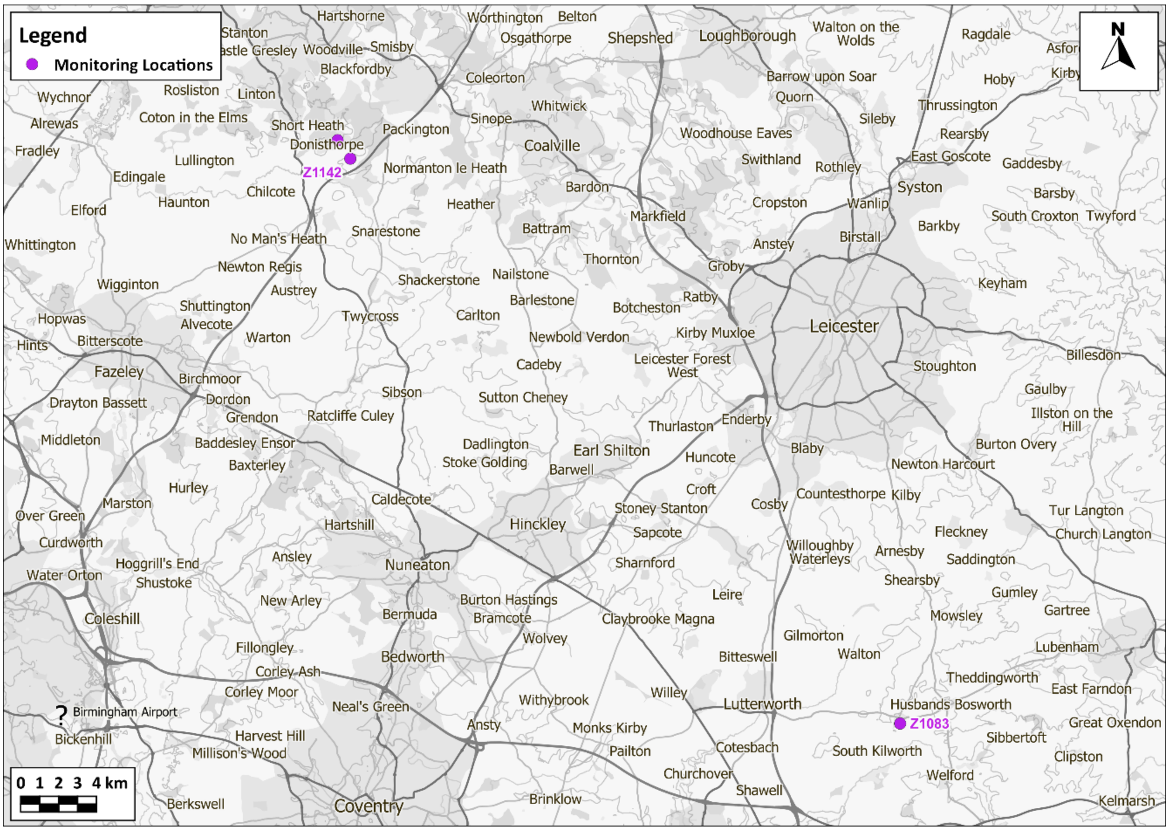


Figure 2: Location of Z1141 (Donisthorpe), Z1142 (Oakthorpe) and Z1083 (North Kilworth)

Imagery ©2023 Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies, The GeoInformation Group.

Monitoring Equipment

3.3 Particulate matter (PM_{10} and $PM_{2.5}$) monitoring was undertaken using Zephyr analysers, which use sensors to measure various parameters, which include $PM_{2.5}$ (µg/m^3), PM_{10} (µg/m^3) and temperature (°C). Measurements were carried out at the three sites for a 12-month period, between 15th September 2022 to 30th September 2023. Although PM_{10} is included in the statistics for comparison with relevant objectives and targets, this report discusses $PM_{2.5}$, which is the focus of the project, has the greatest health effects and is of increasing concern to government, local authorities and the public (see Section 2).

3.4 Zephyrs are not considered to be 'reference equivalent'[3], but have been approved as compliant with the Monitoring Certification Scheme - MCERTS performance standards - as an indicative ambient particulate monitor[4]. The uncertainties and limitations to the use of sensors for monitoring pollutant concentrations are outlined in Section 4.

[3] The definition of 'reference equivalent' refers to a monitoring method that meets a certain standard to ensure accuracy and precision of results – in the UK, monitors that operate within Defra's AURN (Defra, 2023a), are considered to be reference equivalent.

[4] https://www.earthsense.co.uk/post/zephyr-meets-indicative-mcerts

Quality Assurance

3.5 The analysers are calibrated for performance and operation annually, outside of this no quality checks on data check are carried out. By way of validation of the data being recorded, data were downloaded from each monitor periodically ensure the values being recorded were within the expected range and broadly fitted expected patterns.

4 Monitoring Analysis Methodology

4.1 Statistical analysis has been undertaken on the measured pollutant concentrations for the three Zephyrs, for comparison with the air quality criteria outlined in Table 1.

4.2 Further analysis has subsequently been undertaken on the measured concentrations, using 'openair' software, to determine if the monitoring shows any influence of nearby solid fuel burning. As part of this analysis, the results of monitoring (for the same period of time as the Zephyrs) undertaken at three nearby urban background (UB) sites (Leicester University, Northampton Spring Park and Burton-on-Trent Horninglow[5]), operating within the AURN have also been considered – the expectation being that as they are 'background' sites, they would not be influenced by specific pollutant sources, such as nearby domestic solid fuel burning.

4.3 The following plots have been produced:

- Time plots – designed to plot a chronological time series of data, such as pollutant concentration or temperature;
- Time variation plots – this function produces four plots: day-of-the week variation, mean hour-of-day variation and a combined hour-of-day to day-of-week plot and a monthly plot; and
- Polar plots[6] – a bivariate plot of concentrations, varying by wind speed and wind direction.

Uncertainty

4.4 All methods of air quality monitoring have inherent uncertainties. The use of sensors may have additional uncertainties because the analytical chemistry method is more uncertain than reference methods. For example, many sensors are sensitive to changes in atmospheric humidity and temperature, or can give false signals if other air pollutants are present in high concentrations. Additionally, Zephyrs have no form of on-going quality control or calibration applied to them once in the field, unlike reference measurements (Defra, 2023c).

4.5 The Zephyr monitors measured concentrations for one year between 15th September 2022 and 30th September 2023, thus any conclusions drawn based on seasonality should be treated with caution.

4.6 Where data have been extracted for specific dates, times and temperatures to determine whether there is a correlation between measured concentrations and weather conditions, these have been based on judgement about when solid fuel burning is likely to be most prevalent.

5 The Leicester and Burton monitors are FIDAS; the Burton monitor is a BAM (heated) – where applicable, all used measured concentrations used has been corrected to be 'reference equivalent'

6 Modelled meteorological data (wind speed and direction) derived from the WRF (Weather Research and Forecasting Model) have been downloaded for the Leicester University AURN monitor (LECU), as it is deemed the most representative nearby AURN monitoring site.

4.7 The meteorological data used to create the polar plots shown in Appendix A2 are derived using openair**Error! Bookmark not defined.** and are not site-specific to the monitoring locations. As such, definite conclusions cannot be drawn by comparing the measured $PM_{2.5}$ concentrations and wind direction/wind speed, and the meteorological data can only be used to indicate a potential source of $PM_{2.5}$ emissions.

4.8 Significant care is needed when comparing $PM_{2.5}$ measurements made using different monitoring equipment, particularly when comparing analysers such as the Zephyrs with those within the AURN. The analysis is also limited, to some extent, by the interpretation of data from a single monitoring site within each of the villages.

5 Results and Analysis

Simple Statistics

5.1 The particulate matter (PM_{10} and $PM_{2.5}$) concentrations for the three Zephyrs are summarised in Table 2. Data capture was good across the three sites (89.6 – 96.4%) over the monitoring period. The recorded annual mean PM_{10} and $PM_{2.5}$ concentrations were well below the objective and limit value of 40 µg/m^3 and 20 µg/m^3, respectively. The recorded annual mean $PM_{2.5}$ concentration is marginally above the interim target for 2028 (12 µg/m^3) at Z1141. There was only one measured exceedance of the 24-hour mean objective level of 50 µg/m^3 across the three sites, in Donisthorpe (Z1141), compared with the 35 exceedances allowed in a year; at the other sites there were no 24-hour periods measuring more than 50 µg/m^3. The 90th percentile of daily mean concentrations were also well below 50 µg/m^3, at all sites.

Table 2: Particulate Matter Data Summary for Z1141, Z1142 and Z1083, September 2022 to September 2023

Pollutant	Metric	Z1141 (Donisthorpe)	Z1142 (Oakthorpe)	Z1083 (North Kilworth)	Objectives
PM_{10}	Maximum 24-hour Mean	212.6 µg/m^3	41.2 µg/m^3	36.7 µg/m^3	-
	No. 24-Hour Means >50 µg/m^3	1	0	0	50 µg/m^3; no more than 35 exceedances
	90th Percentile	25.4 µg/m^3	25.3 µg/m^3	21.7 µg/m^3	50 µg/m^3
	Period Mean (12months)	13.7 µg/m^3	12.0 µg/m^3	13.7 µg/m^3	40 µg/m^3
$PM_{2.5}$	Period Mean (12months)	12.4 µg/m^3	11.0 µg/m^3	9.9 µg/m^3	20 µg/m^3
	Data Capture	89.6%	96.4%	95.9%	-

'openair' Analysis

5.2 Figures showing the local Zephyr measurements, as well as measurements from the AURN sites, and an analysis of results are set out in Appendix A2. The data have been examined specifically to find any signal that solid fuel burning is taking place in the vicinity, and comments are included to that effect within Appendix A2. Evidence of the effects of Solid Fuel Burning are not clear cut, for a number of reasons, which are set out in paragraphs 2.6 and 2.7 and in Appendix A2.

6 Conclusions

6.1 A 12-month PM_{10} and $PM_{2.5}$ monitoring programme was carried out in three villages (Donisthorpe, Oakthorpe and North Kilworth) in NWL and Harborough. The monitoring was funded through a grant funded project awarded to NWL and Harborough District Councils, to support work to increase public awareness of the air quality impacts of solid-fuel burning. This report provides an overview of the monitoring results, to try to identify any quantified evidence of domestic solid fuel burning in the three villages.

6.2 Measured concentrations are below national air quality objectives/targets at the three monitoring sites during the 12-month monitoring period, other than at Donisthorpe which is marginally over the target value for 2028.

6.3 Detailed statistical analysis of the monitoring results, using 'openair' software included in Appendix A2, has not identified any clear influences from solid fuel burning in the vicinity of the any of the monitors. The plots produced seem to show periods of higher concentrations, at times, during colder temperatures, during the evening and over the weekend, which could be interpreted as times when residents are more likely to be burning solid fuel, however, as noted in Section 2, variations in $PM_{2.5}$ can occur for multiple reasons, due to source, meteorology, chemistry or measurement method; in the absence of a clear signal from the monitoring data and its subsequent analysis, it is concluded that data are not clear enough to draw a conclusion as to what is driving these elevated concentrations.

7 References

Air Quality Expert Group. (2012). *Fine Particulate Matter (PM2.5) in the United Kingdom.*

Carslaw, D. R. (2012). openair — An R package for air quality data analysis. *Science Direct*, 52-61.

Defra. (2023a). *Defra AURN Archive.* Retrieved from https://uk-air.defra.gov.uk/interactive-map?network=aurn

Defra. (2023b). *Particulate Matter*. Retrieved from https://www.gov.uk/government/statistics/air-quality-statistics/concentrations-of-particulate-matter-pm10-and-pm25

Defra. (2023c). *Low cost pollution sensor - understanding uncertainties*. Retrieved from https://uk-air.defra.gov.uk/research/aqeg/pollution-sensors/understanding-uncertainties.php#:~:text=For%20example%2C%20many%20sensors%20are,are%20present%20in%20high%20concentrations

Environment Act 2021. (2021).

8 Appendices

A1 Summary of AURN Results

A1.1 Particulate matter (PM_{10} and $PM_{2.5}$) concentrations, for three urban background sites within the AURN network, within 50 miles of the Zephyr sites, for the same period of monitoring (September 2022 to September 2023) are summarised in Table A1.1. Measured concentrations (across parameters) at all of the Zephyrs were higher than the AURN background concentrations.

Table A1.1: PM_{10} Data Summary of Background Monitoring Sites, 2022

Pollutant	Statistic	Leicester University	Northampton Spring Park[a]	Burton on Trent Horninglow
PM_{10}	Maximum 24-hr mean ($\mu g/m^3$)	47.5	n/a	45.6
	No. 24-hr mean >50 $\mu g/m^3$	0	n/a	0
	90^{th} Percentile	19.7	n/a	19.5
	Period Mean ($\mu g/m^3$)	11.7	n/a	12.1
$PM_{2.5}$	Period Mean ($\mu g/m^3$)	7.3	7.6	7.5
	Data Capture (%)	98.0	89.0	56.4

[a] This site does not measure PM_{10}.

A2 'openair' Plots

Donisthorpe (Z1141)

Time Plots

A2.1 Figure A2.1 shows a time series plot of daily mean $PM_{2.5}$ concentrations at site Z1141. It also shows the daily mean $PM_{2.5}$ averaged across each of the AURN sites and the daily average recorded temperature. A visual examination of the data shows that the Zephyr and AURN average follow broadly similar patterns and that, where there are differences between the two; these differences appear on visual inspection to be smaller than the shared range in the two sets of concentrations. The highest concentrations at both types of sites appear to broadly coincide with the lowest air temperatures, with the data also showing some elevated concentrations in spring and late summer. It is difficult to say whether the higher concentrations which coincide with lower temperatures are caused by solid fuel burning, for the reasons set out in paragraphs 2.6 and 2.7.

Time Variation Plots

A2.2 Figure A2.2 shows measured data according to day-of-the-week, month-of-the-year and time-of-the-day, across the monitoring period; the plot indicates elevated concentrations in the evening time, in particular during September to December 2022 and on a Sunday in general.

A2.3 Figure A2.3, which shows measured data according to temperature[12], indicates elevated concentrations during times when temperatures are below 10°C and in the evening time in general. This is a common observation which often correlates with the condensing of ammonium nitrate. The increase in Sunday concentrations appears to be caused at times where the temperature is over 10 degrees and hence is unlikely to be as a result of solid fuel burning.

Polar plots

A2.4 Figure A2.4 shows the measured concentrations as a function of wind direction and wind speed. The colour shows the measured concentration, the direction from the centre of the plot (where the horizontal and vertical black lines cross) shows the wind direction, and the distance from the centre shows the wind speed when that concentration was measured. It is often the case that sources which are some distance away, or released from tall chimneys, are associated with higher wind speeds, which bring plumes back to ground. Nearby sources which emit close to ground are often associated with slower wind speeds, which could indicate an influence from domestic solid fuel burning, but there can also be many other reasons for higher concentrations when wind speeds are low and hence it is difficult to attribute it to a specific source with any certainty.

A2.5 Figure A2.4a, which shows measured data during cold winter nights[7], shows the highest concentrations occurred during the lowest wind speeds (centre of the plot), and from all wind directions. The all-other time plot (Figure A2.4b) shows the highest concentrations occurred at slow wind speeds, with higher concentrations also when winds were from the east and southeast. Higher concentrations tend to be associated with stronger winds from the south and northeast when the temperature was cold, and from the east and southeast when it was warmer.

[7] 'Cold winter nights' are defined in this study as any temperature <10°C, 6 pm to midnight, between 1st November 2022 to 1st March 2023.

Figure A2.1: Time series plot of daily mean $PM_{2.5}$ concentrations (µg/m^3) at Z1141 (blue), average AURN $PM_{2.5}$ concentrations (µg/m^3) (red) and temperature (at Zephyr) (°C) (green), September 2022 to September 2023

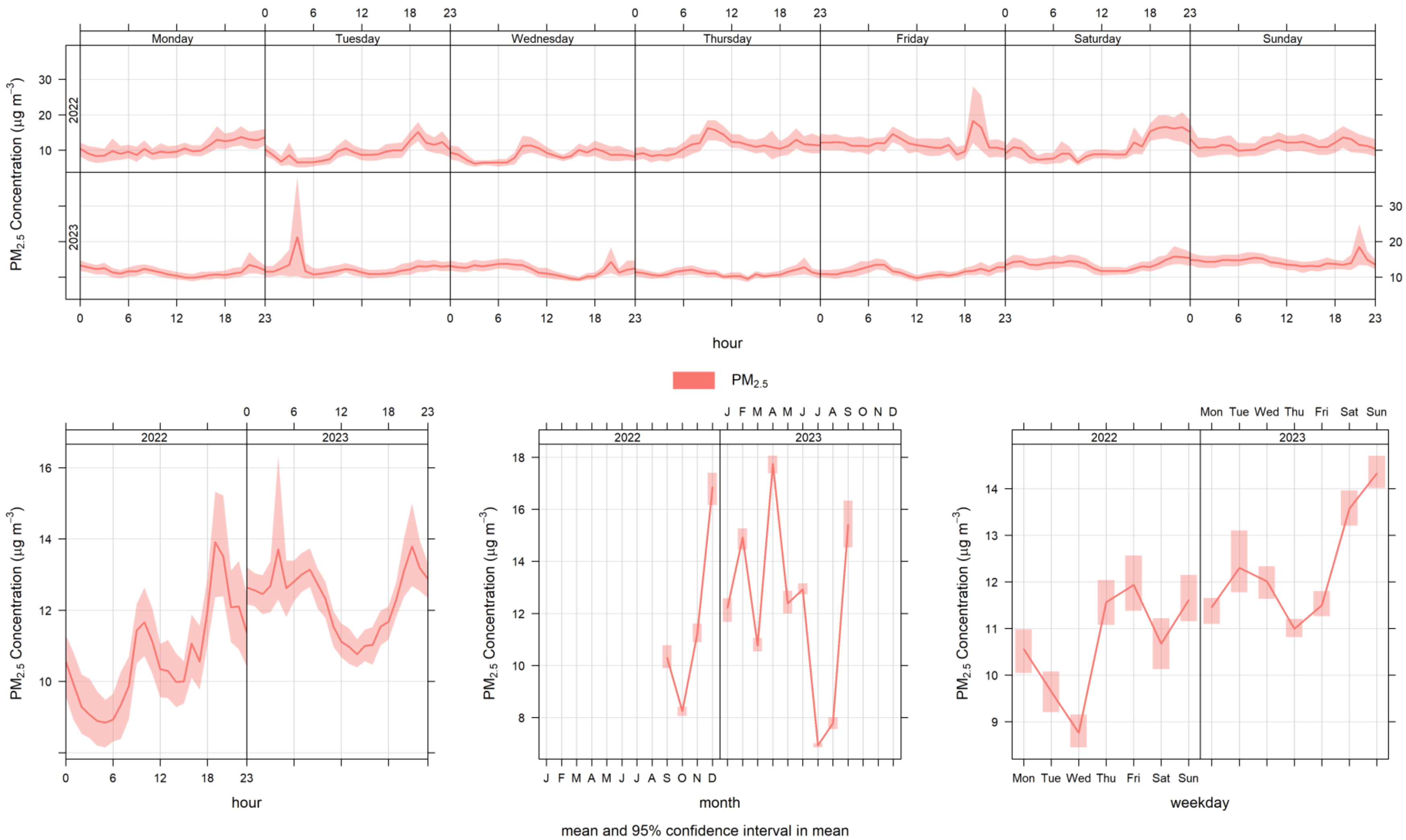


Figure A2.2: Time variation plot of measured $PM_{2.5}$ concentrations (µg/m^3) at Z1141, September 2022 to September 2023

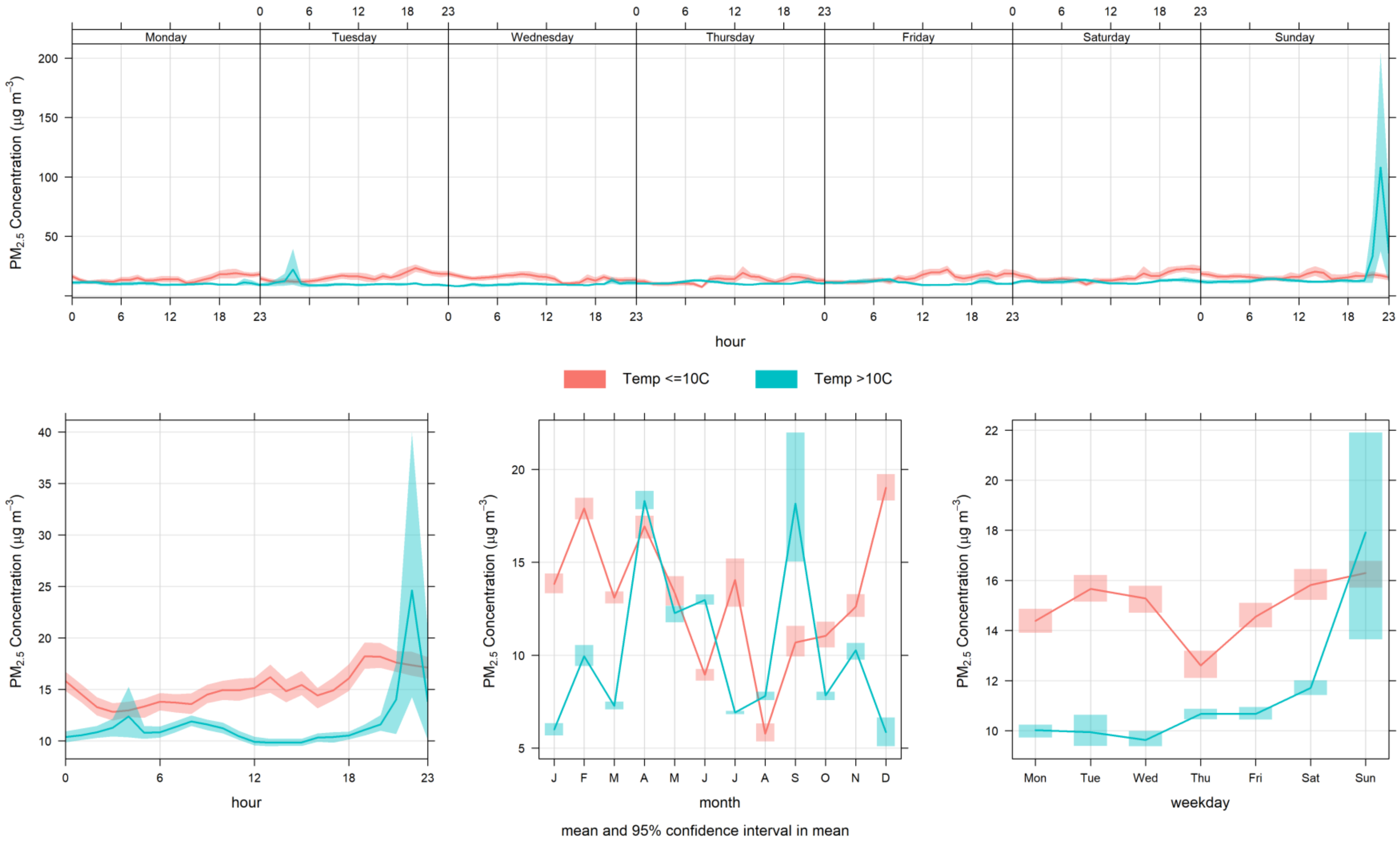


Figure A2.3: Time variation plot of measured $PM_{2.5}$ concentrations (µg/m³) at Z1141, September 2022 to September 2023, with concentrations separated according to whether the ambient temperature was greater, or less than, 10°C

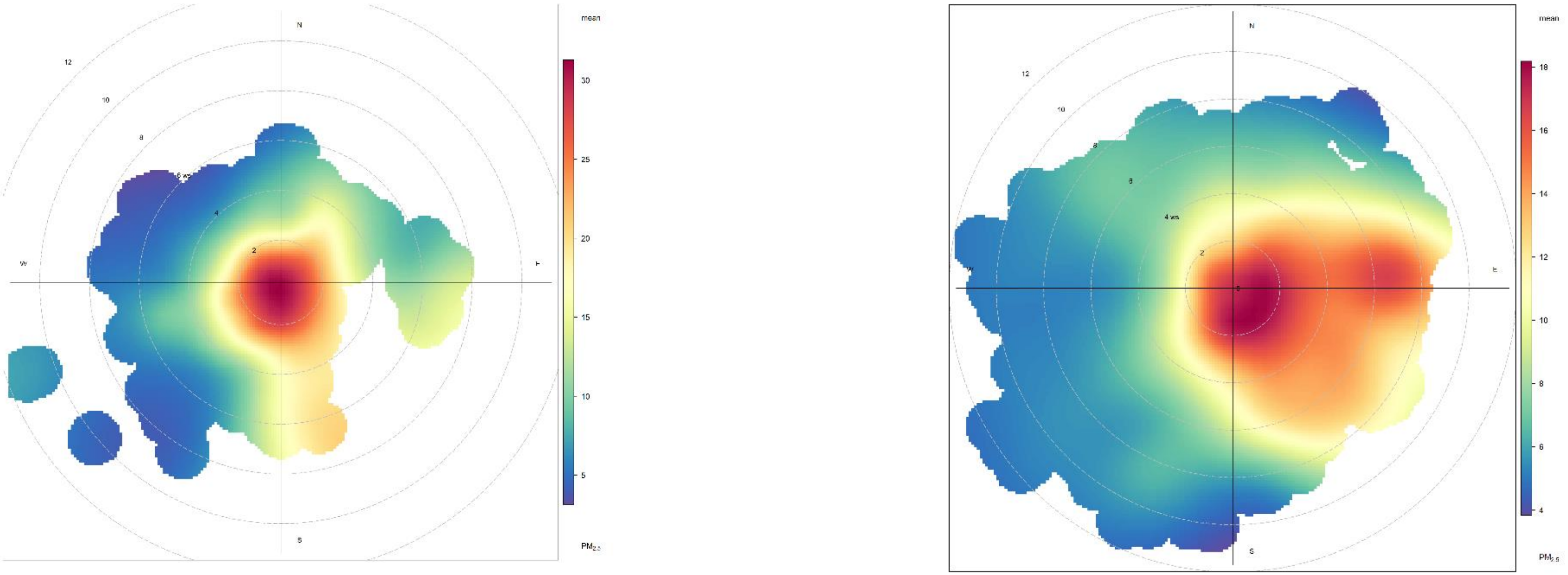


Figure A2.4: Bivariate Pollution Roses at Z1141, September 2022 to September 2023, accounting for 'cold winter nights'[8] (a - left) and rest of the period (b - right), $PM_{2.5}$ (µg/m^3)

[8] 'Cold winter nights' are defined in this study as any temperature <10°C, 6 pm to midnight, between 1st November 2022 to 1st March 2023.

Oakthorpe (Z1142)

Time Plots

A2.6 Figure A2.5 shows a similar pattern over time at Z1142 and the AURN sites. A visual examination of the data shows that the Zephyr and AURN average follow broadly similar patterns and that, where there are differences between the two; these differences appear on visual inspection to be smaller than the shared range in the two sets of concentrations. The highest concentrations at both types of sites appear to broadly coincide with the lowest air temperatures, with the data also showing some elevated concentrations in spring and late summer. It is difficult to say whether the higher concentrations which coincide with lower temperatures are caused by solid fuel burning, for the reasons set out in paragraphs 2.6 and 2.7.

Time Variation Plots

A2.7 Figure A2.6 shows measured data, according to day-of-the-week, month-of-the-year or time-of-the-day, across the monitoring period; the plot indicates elevated concentrations in the evening time, and on Thursday through to Sunday during September to December 2022, which may coincide with times of higher solid fuel burning.

A2.8 Figure A2.7, which shows measured data according to temperature, indicates elevated concentrations during times when temperatures are below 10°C, in the evening time in general and on Saturday and Sunday, which again, could indicate an influence from domestic solid fuel burning, although as discussed, it is difficult to attribute the elevated concentrations to this source with certainty.

Polar plots

A2.9 Figure A2.8a, which shows measured data during cold winter nights[9], shows the highest concentrations occurred during the lowest wind speeds (centre of the plot) from all wind directions and also at higher windspeeds when winds blew from the south. The all-other time plot (Figure A2.8b) has a stronger signal from the east and southeasterly directions. These are most likely to reflect long-range transport, although local sources, such as domestic solid fuel burning, may also affect the observed patterns.

[9] 'Cold winter nights' are defined in this study as any temperature <10°C, 6 pm to midnight, between 1st November 2022 to 1st March 2023.

Figure A2.5: Time series plot of daily mean $PM_{2.5}$ concentrations (µg/m³) at Z1142 (blue), average AURN $PM_{2.5}$ concentrations (µg/m³) (red) and temperature (at Zephyr) (°C) (green), September 2022 to September 2023

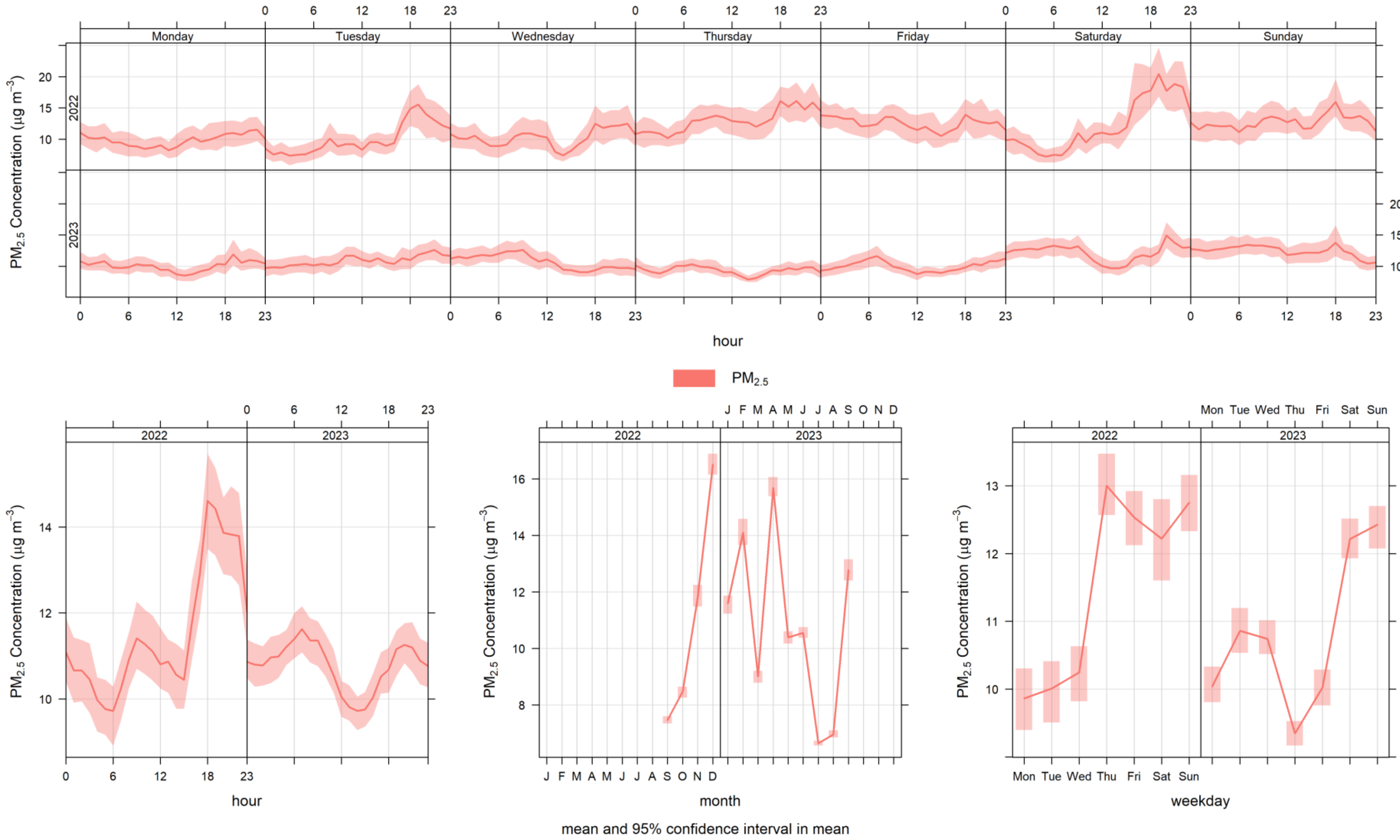


Figure A2.6: Time variation plot of measured $PM_{2.5}$ concentrations (µg/m^3) at Z1142, September 2022 to September 2023

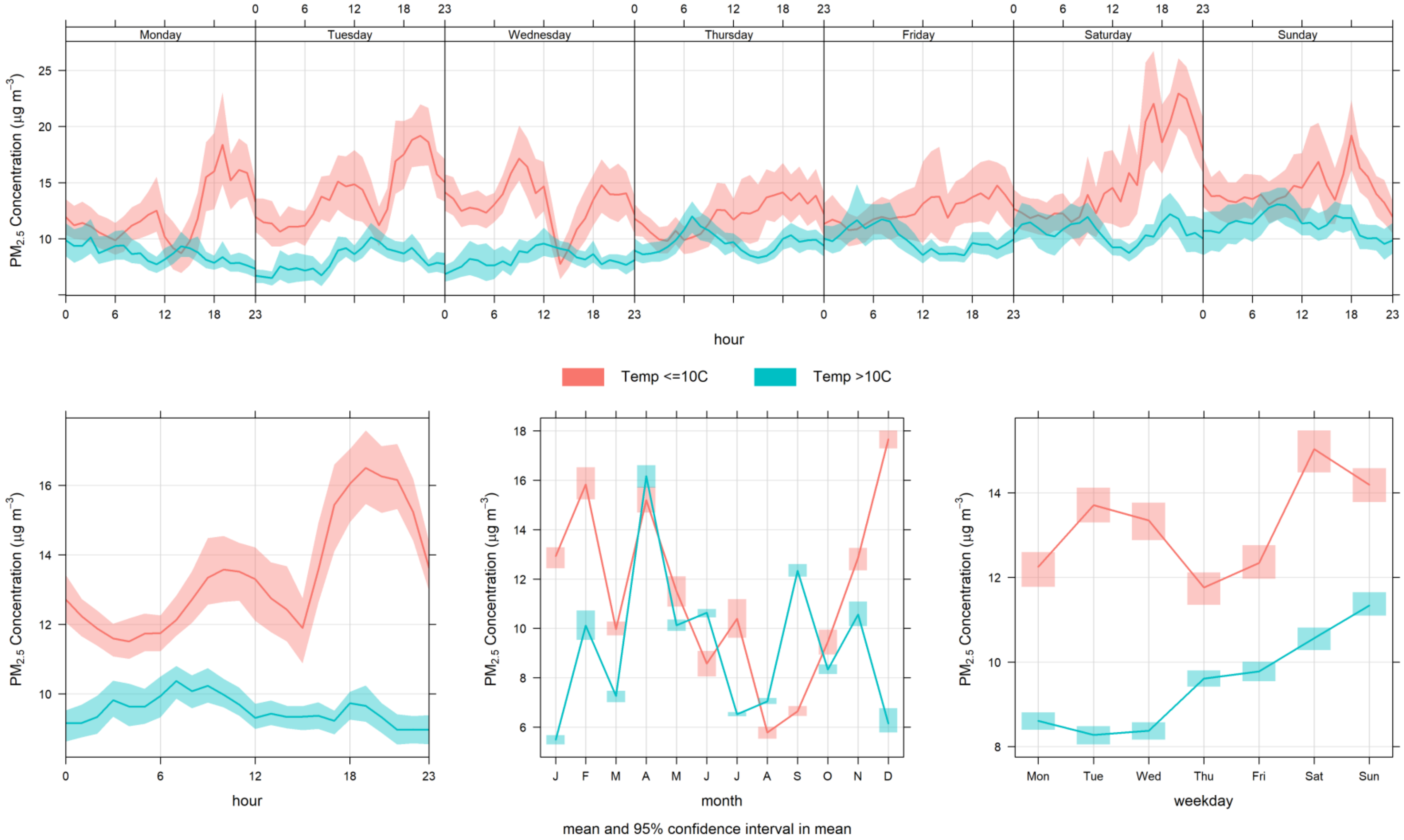


Figure A2.7: Time variation plot of measured $PM_{2.5}$ concentrations (µg/m³) at Z1142, September 2022 to September 2023, with concentrations separated according to whether the ambient temperature was greater, or less than, 10°C

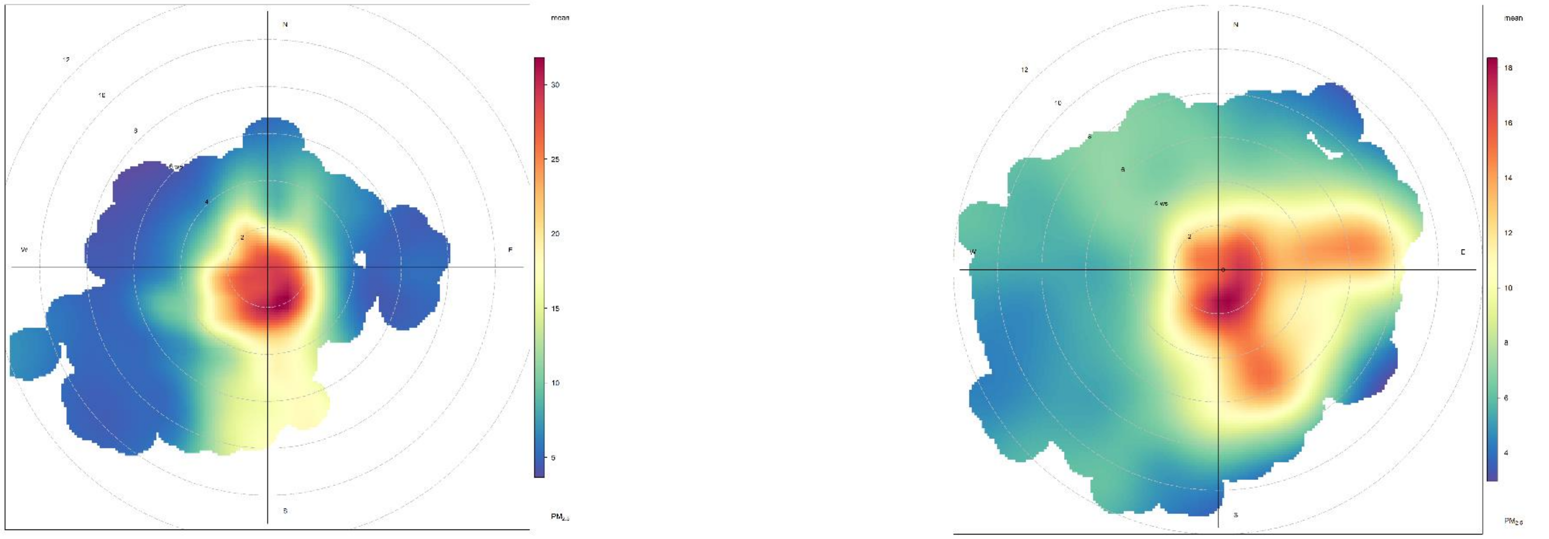


Figure A2.8: Bivariate Pollution Roses at Z1142, September 2022 to September 2023, accounting for 'cold winter nights'[10] (a - left) and rest of the period (b - right), $PM_{2.5}$ (µg/m^3)

North Kilworth (Z1083)

Time Plots

A2.10 Figure A2.9 shows a similar pattern over time at Z1083 and the AURN sites. A visual examination of the data shows that the Zephyr and AURN average follow broadly similar patterns and that, where there are differences between the two; these differences appear on visual inspection to be smaller than the shared range in the two sets of concentrations. The highest concentrations at both types of sites appear to broadly coincide with the lowest air temperatures, with the data also showing some elevated concentrations in spring and late summer. It is difficult to say whether the higher concentrations which coincide with lower temperatures are caused by solid fuel burning, for the reasons set out in paragraphs 2.6 and 2.7.

Time Variation Plots

A2.11 Figure A2.10 shows measured data, according to day-of-the-week, month-of-the-year and time-of-the-day, across the monitoring period; the plot indicates elevated concentrations on Thursday, Friday and Sunday during September to December 2022 and on Saturday and Sunday during January to September 2023. There also appear to be elevated concentrations in the morning. It is difficult to attribute these patterns to domestic solid fuel burning.

A2.12 Figure A2.11, which shows measured data according to temperature, clearly indicates elevated concentrations during times when temperatures are below 10°C, which could be attributable to domestic solid burning, but for reasons already set out, it is difficult to be definitive regarding source.

Polar plots

A2.13 Figure A2.12a, which shows measured data during cold winter nights, shows the highest concentrations occurred during the lowest wind speeds (centre of the plot), from all wind directions. The all-other time plot (Figure A2.12b) shows the highest concentrations also occur during a range of wind speeds, during winds with a southern and easterly component. The higher concentrations at lower windspeeds indicate the potential predominance of a local source, such as domestic solid fuel burning, but it is difficult to be definitive on sources of $PM_{2.5}$.

Figure A2.9: Time series plot of daily mean $PM_{2.5}$ concentrations (µg/m^3) at Z1083 (blue), average AURN $PM_{2.5}$ concentrations (µg/m^3) (red) and temperature (at Zephyr) (°C) (green), September 2022 to September 2023

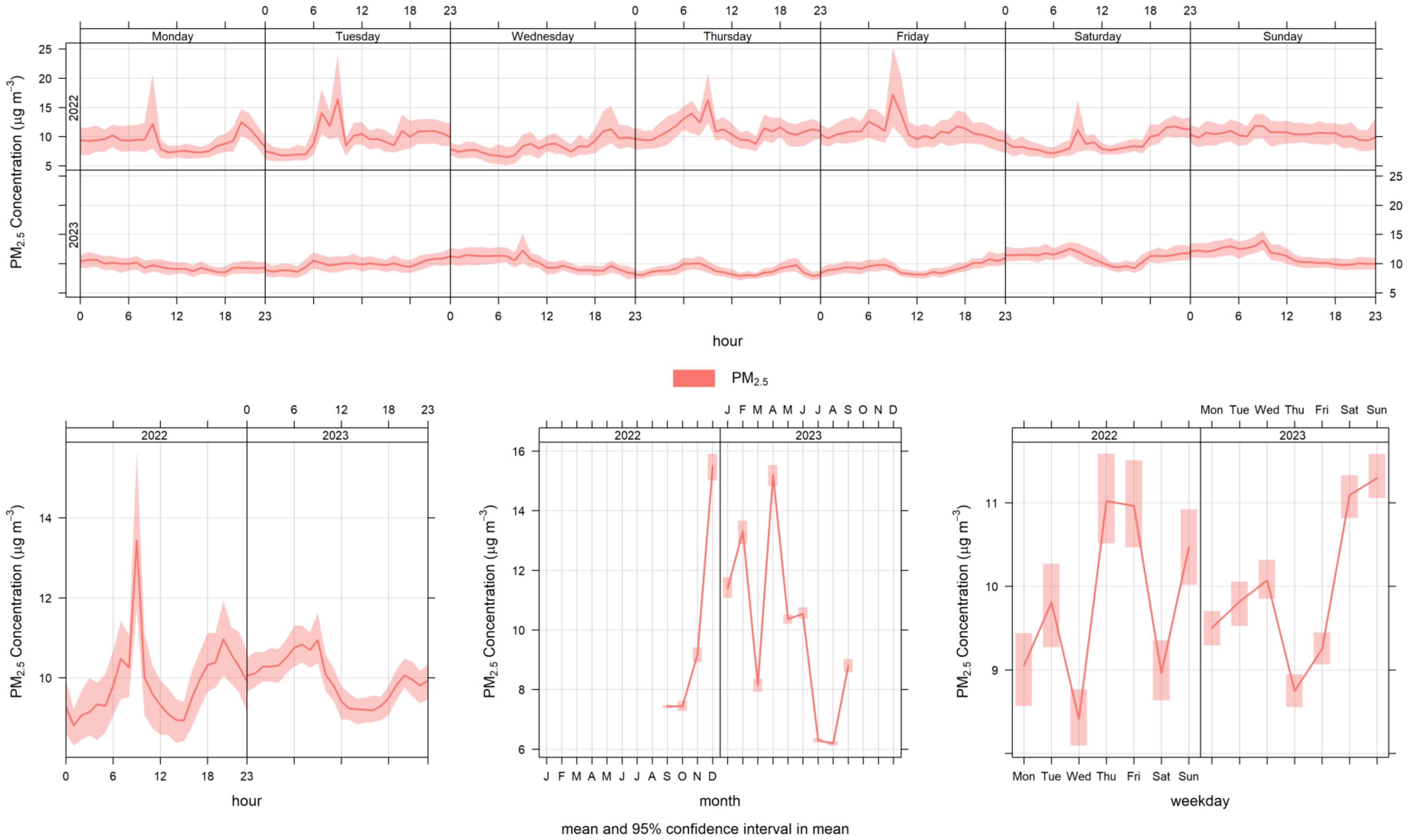


Figure A2.10: Time variation plot of measured $PM_{2.5}$ concentrations (µg/m^3) at Z1083, September 2022 to September 2023

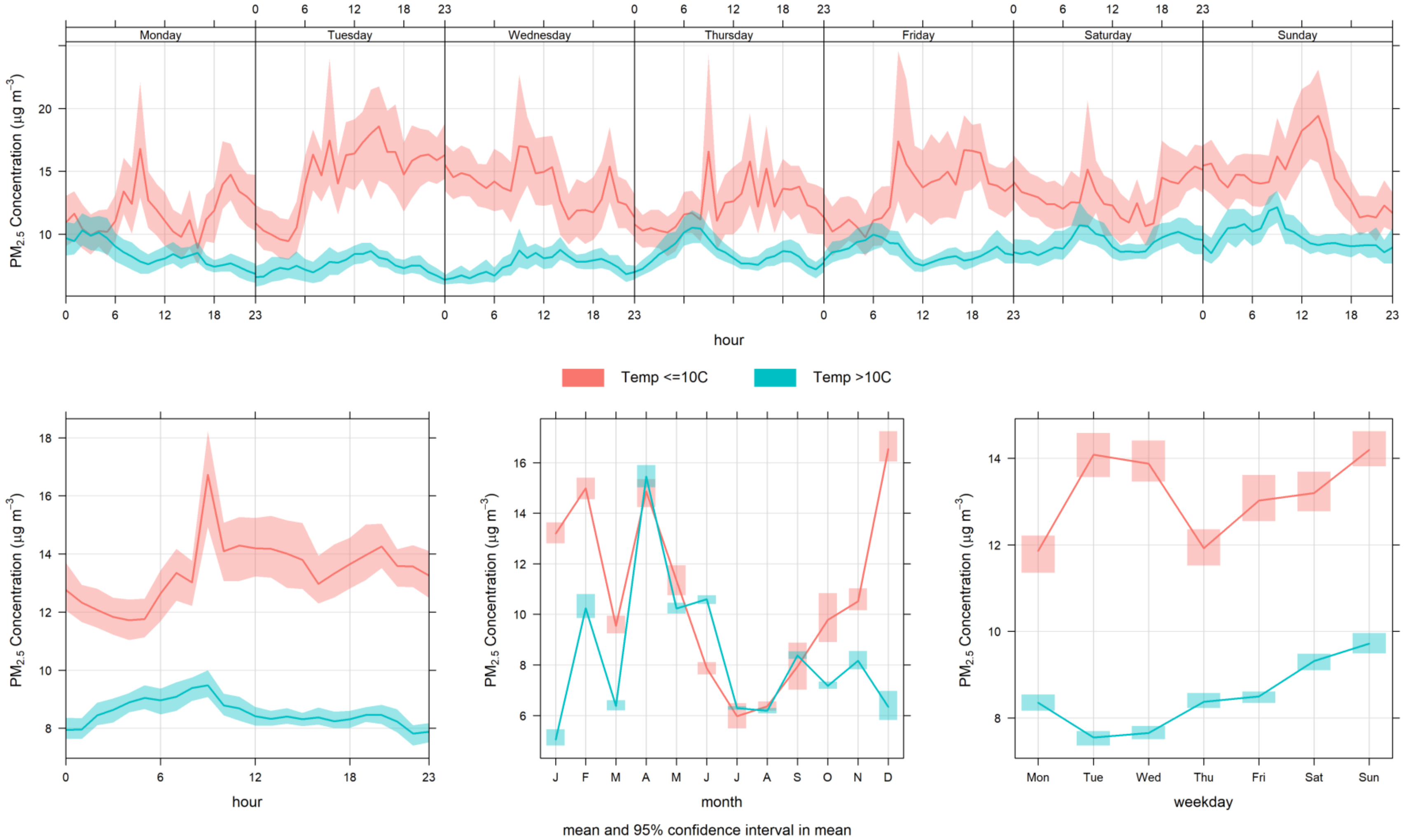
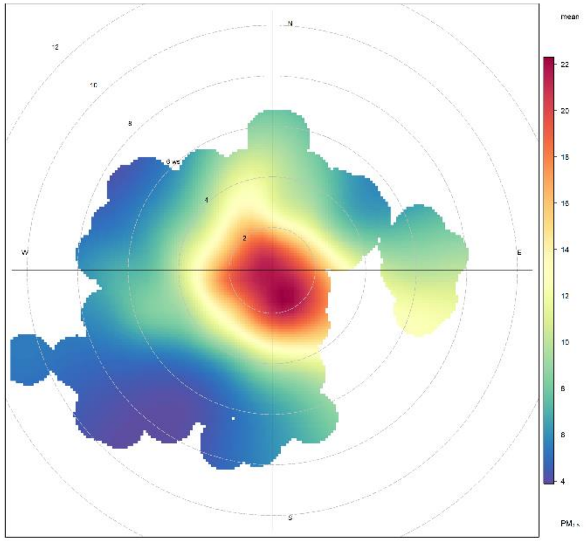


Figure A2.11: Time variation plot of measured $PM_{2.5}$ concentrations (µg/m^3) at Z1083, September 2022 to September 2023, with concentrations separated according to whether the ambient temperature was greater, or less than, 10^{o}C



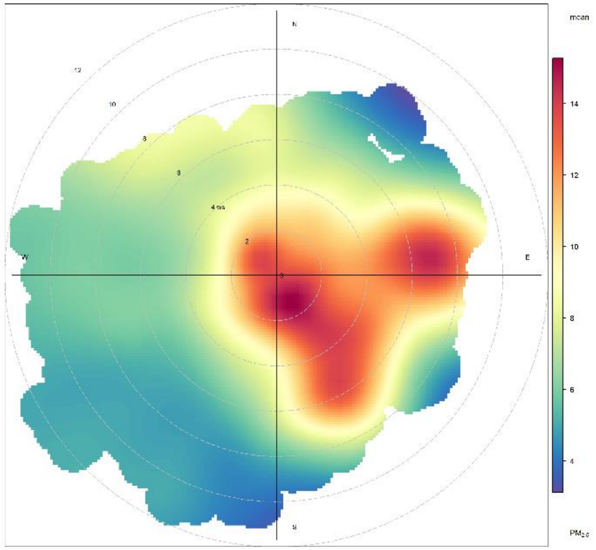


Figure A2.12: Bivariate Pollution Roses at Z1083, September 2022 to September 2023, accounting for 'cold winter nights'[10] (a - left) and rest of the period (b - right), $PM_{2.5}$ (µg/m^3)