Appendix K  Wind Speed and Direction and Pollutant Concentrations

K1.1 Correction of Wind Speed and Direction

This section details the method used to correct mobile measurements of wind speed and direction.

One-minute average measurements of wind speed and direction were recorded during the mobile monitoring exercises. These data were corrected in order to take account of the relative heading and speed of the mobile monitoring trolley during each exercise. Heading measurements were taken using the Lufft met mast and speed measurements were recorded using the GPS watch. Figure K1 shows an example of measured wind and heading vectors together with the calculated resultant wind vector and 4 quadrants.

*Figure K1 Measured Wind, Measured Heading and Resultant Vectors*

1. Measured wind vector
2. Measured heading vector
3. Resultant wind vector

The following equations were used to calculate the resultant wind vector:
where:

- \( w \) = the measured wind speed.
- \( w_h \) = the measured walking speed.
- \( u \) = the horizontal component of the measured wind speed.
- \( v \) = the vertical component of the measured wind speed.
- \( u_h \) = the horizontal component of the measured walking speed.
- \( v_h \) = the vertical component of the measured walking speed.
- \( \theta \) = angle of measured wind vector relative to the 180°/360° axis.
- \( \phi \) = angle of measured heading vector relative to the 180°/360° axis.
- \( \Delta u \) = the difference between the horizontal components of measured wind speed and walking speed.
- \( \Delta v \) = the difference between the vertical components of measured wind speed and walking speed.
- \( x \) = the resultant wind speed.
- \( \alpha \) = Angle of resultant wind vector relative to the 180°/360° axis.

The following equations were used in order to convert the angle of the resultant wind vector relative to the 180°/360° axis \((\alpha)\) to a resultant wind direction \((\delta)\):

\[
\begin{align*}
I f \: + \Delta u \: and \: + \Delta v \: t h e n: \quad \delta &= \alpha \\
I f \: + \Delta u \: and \: - \Delta v \: t h e n: \quad \delta &= 180^\circ - \alpha \\
I f \: - \Delta u \: and \: - \Delta v \: t h e n: \quad \delta &= 180^\circ + \alpha \\
I f \: - \Delta u \: and \: + \Delta v \: t h e n: \quad \delta &= 360^\circ - \alpha
\end{align*}
\]
Figure K2 is the wind rose of 1-minute average wind data as measured during all mobile monitoring exercises and Figure K3 shows the corrected wind rose. Wind roses for each individual mobile monitoring exercise are shown in Figure K6 and Figure K7.

**Figure K2 Wind Rose – All Mobile Exercises**

![Wind rose diagram](image)
**K1.2 Summary Statistics - Wind Speed and Direction**

**Table K 1 Summary Statistics of Wind Direction and Speed – Mobile Monitoring Exercises**

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Channel</th>
<th>14-Mar</th>
<th>21-May</th>
<th>Jun-Jul</th>
<th>Jul-Aug</th>
<th>Jul-All</th>
<th>Aug-All</th>
<th>ALL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Min</strong></td>
<td>Wind</td>
<td>0.20</td>
<td>0.01</td>
<td>0.50</td>
<td>1.00</td>
<td>7.90</td>
<td>7.14</td>
<td>0.33</td>
</tr>
<tr>
<td><strong>2nd Q</strong></td>
<td></td>
<td>63.68</td>
<td>56.34</td>
<td>114.40</td>
<td>89.58</td>
<td>91.49</td>
<td>80.98</td>
<td>85.42</td>
</tr>
<tr>
<td><strong>Med</strong></td>
<td></td>
<td>144.90</td>
<td>101.40</td>
<td>196.00</td>
<td>172.60</td>
<td>190.90</td>
<td>191.30</td>
<td>170.10</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td></td>
<td>152.30</td>
<td>140.90</td>
<td>184.40</td>
<td>174.70</td>
<td>178.10</td>
<td>175.60</td>
<td>165.80</td>
</tr>
<tr>
<td><strong>3rd Q</strong></td>
<td></td>
<td>223.00</td>
<td>223.50</td>
<td>255.00</td>
<td>245.50</td>
<td>253.90</td>
<td>256.00</td>
<td>258.10</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td></td>
<td>359.60</td>
<td>359.00</td>
<td>355.80</td>
<td>356.30</td>
<td>355.70</td>
<td>359.80</td>
<td>353.30</td>
</tr>
</tbody>
</table>

Frequency of counts by wind direction (%)

**Figure K3 Corrected Wind Rose – All Mobile Exercises**
## Air Quality Study - Scotland

### Table: Wind Speed

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Channel</th>
<th>Mobile Exercises (°, m s⁻¹)</th>
<th>14-Mar</th>
<th>21-May</th>
<th>23-Jun</th>
<th>28-Jun</th>
<th>08-Jul</th>
<th>13-Jul</th>
<th>09-Aug</th>
<th>15-Aug</th>
<th>ALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>Wind Speed</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
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<tr>
<td>2nd Q</td>
<td>Wind Speed</td>
<td>1.8</td>
<td>1.4</td>
<td>1.7</td>
<td>1.5</td>
<td>1.7</td>
<td>1.6</td>
<td>1.4</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Med</td>
<td>Wind Speed</td>
<td>3.0</td>
<td>2.2</td>
<td>2.6</td>
<td>2.1</td>
<td>2.6</td>
<td>2.4</td>
<td>1.9</td>
<td>2.0</td>
<td>2.6</td>
<td>2.3</td>
</tr>
<tr>
<td>Mean</td>
<td>Wind Speed</td>
<td>3.2</td>
<td>2.4</td>
<td>2.6</td>
<td>2.2</td>
<td>2.8</td>
<td>2.7</td>
<td>2.0</td>
<td>2.6</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>3rd Q</td>
<td>Wind Speed</td>
<td>4.4</td>
<td>3.2</td>
<td>3.4</td>
<td>2.8</td>
<td>3.6</td>
<td>3.4</td>
<td>2.5</td>
<td>3.3</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Max</td>
<td>Wind Speed</td>
<td>8.2</td>
<td>8.0</td>
<td>6.1</td>
<td>4.8</td>
<td>13.2</td>
<td>16.3</td>
<td>7.0</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
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</tbody>
</table>

### Figure K4 Box Plot of Wind Direction – Mobile Monitoring Exercises

![Box Plot of Wind Direction](image1)

### Figure K5 Box Plot of Wind Speed – Mobile Monitoring Exercises

![Box Plot of Wind Speed](image2)
K1.3 Corrected Wind Roses by Day and Street

*Figure K6 Corrected Wind Roses – 14-Mar, 21-May, 23-Jun and 08-Jul*
Figure K7 Corrected Wind Roses – 13-Jul, 09-Aug and 15-Aug

13-Jun

<table>
<thead>
<tr>
<th>Wind Direction</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>5%</td>
</tr>
<tr>
<td>S</td>
<td>10%</td>
</tr>
<tr>
<td>N</td>
<td>15%</td>
</tr>
<tr>
<td>E</td>
<td>20%</td>
</tr>
</tbody>
</table>

Mean = 2.79
Calm = 0%

0 to 2
2 to 4
4 to 6
6 to 13.205
(m s⁻¹)

15-Aug

<table>
<thead>
<tr>
<th>Wind Direction</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>5%</td>
</tr>
<tr>
<td>S</td>
<td>10%</td>
</tr>
<tr>
<td>N</td>
<td>15%</td>
</tr>
<tr>
<td>E</td>
<td>20%</td>
</tr>
</tbody>
</table>

Mean = 2.52
Calm = 0%

0 to 2
2 to 4
4 to 6
6 to 6.9725
(m s⁻¹)

09-Aug

<table>
<thead>
<tr>
<th>Wind Direction</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>5%</td>
</tr>
<tr>
<td>S</td>
<td>10%</td>
</tr>
<tr>
<td>N</td>
<td>15%</td>
</tr>
<tr>
<td>E</td>
<td>25%</td>
</tr>
</tbody>
</table>

Mean = 2.68
Calm = 0%

0 to 2
2 to 4
4 to 6
6 to 16.329
(m s⁻¹)
Figure K8 Wind Roses – Hope St, Sauchiehall St/Buchanan St and High St

Wind Rose - Hope St

Frequency of counts by wind direction (%)

Wind Rose - Buchanan St

Frequency of counts by wind direction (%)

Wind Rose - High St

Frequency of counts by wind direction (%)

Mean = 2.03
Calm = 0%

0 to 2 2 to 4 4 to 6 6 to 9
(m s⁻¹)

Mean = 2.82
Calm = 0%

0 to 2 2 to 4 4 to 6 6 to 6.8
(m s⁻¹)

Mean = 2.95
Calm = 0%

0 to 2 2 to 4 4 to 6 6 to 14.9
(m s⁻¹)
K1.4 Polar Plots

Figure K9 Polar Plots – BC, UFP, PM$_{0.5}$ and PM$_{1.0}$

BC (µg m$^{-3}$) - 0.80 m

BC (µg m$^{-3}$) - 1.68 m

UFP (N Particles cm$^{-3}$) - 0.80 m

UFP (N Particles cm$^{-3}$) - 1.68 m

PM$_{0.5}$ (µg m$^{-3}$) - 0.80 m

PM$_{0.5}$ (µg m$^{-3}$) - 1.68 m

PM$_{1}$ (µg m$^{-3}$) - 0.80 m

PM$_{1}$ (µg m$^{-3}$) - 1.68 m
Figure K10 Polar Plots – PM$_{2.5}$, PM$_{5.0}$, PM$_{10}$ and TPM

PM$_{2.5}$ (µg m$^{-3}$) - 0.80 m

PM$_{2.5}$ (µg m$^{-3}$) - 1.68 m

PM$_{5}$ (µg m$^{-3}$) - 0.80 m

PM$_{5}$ (µg m$^{-3}$) - 1.68 m

PM$_{10}$ (µg m$^{-3}$) - 0.80 m

PM$_{10}$ (µg m$^{-3}$) - 1.68 m

TPM (µg m$^{-3}$) - 0.80 m

TPM (µg m$^{-3}$) - 1.68 m
Figure K11 Polar Plots – NO₂, NO, CO and SO₂

NO₂ (µg m⁻³) - 0.80 m

NO₂ (µg m⁻³) - 1.68 m

NO (µg m⁻³) - 0.80 m

NO (µg m⁻³) - 1.68 m

CO (µg m⁻³) - 0.80 m

CO (µg m⁻³) - 1.68 m

SO₂ (µg m⁻³) - 0.80 m

SO₂ (µg m⁻³) - 1.68 m
Figure K12 Polar Plots of BC, UFP, PM$_{0.5}$ and PM$_{1.0}$ – Hope St

BC (µg m$^{-3}$) - 0.80 m

BC (µg m$^{-3}$) - 1.68 m

UFP (N Particles cm$^{-3}$) - 0.80 m

UFP (N Particles cm$^{-3}$) - 1.68 m

PM$_{0.5}$ (µg m$^{-3}$) - 0.80 m

PM$_{0.5}$ (µg m$^{-3}$) - 1.68 m

PM$_{1}$ (µg m$^{-3}$) - 0.80 m

PM$_{1}$ (µg m$^{-3}$) - 1.68 m
Figure K13 Polar Plots of PM$_{2.5}$, PM$_{5.0}$, PM$_{10}$ and TPM – Hope St

PM$_{2.5}$ ($\mu$g m$^{-3}$) - 0.80 m

PM$_{5}$ ($\mu$g m$^{-3}$) - 0.80 m

PM$_{10}$ ($\mu$g m$^{-3}$) - 0.80 m

TPM ($\mu$g m$^{-3}$) - 0.80 m

PM$_{2.5}$ ($\mu$g m$^{-3}$) - 1.68 m

PM$_{5}$ ($\mu$g m$^{-3}$) - 1.68 m

PM$_{10}$ ($\mu$g m$^{-3}$) - 1.68 m

TPM ($\mu$g m$^{-3}$) - 1.68 m
Figure K14 Polar Plots of $\text{NO}_2$, $\text{NO}$, $\text{CO}$ and $\text{SO}_2$ – Hope St

- $\text{NO}_2$ ($\mu g \, m^{-3}$) - 0.80 m
- $\text{NO}_2$ ($\mu g \, m^{-3}$) - 1.68 m
- $\text{NO}$ ($\mu g \, m^{-3}$) - 0.80 m
- $\text{NO}$ ($\mu g \, m^{-3}$) - 1.68 m
- $\text{CO}$ ($\mu g \, m^{-3}$) - 0.80 m
- $\text{CO}$ ($\mu g \, m^{-3}$) - 1.68 m
- $\text{SO}_2$ ($\mu g \, m^{-3}$) - 0.80 m
- $\text{SO}_2$ ($\mu g \, m^{-3}$) - 1.68 m
Figure K15 Polar Plots of BC, UFP, PM$_{0.5}$ and PM$_{1.0}$ – Sauchiehall St/Buchanan St

- **BC (µg m$^{-3}$) - 0.80 m**
  - Mean values range from 0.8 to 2.2 µg m$^{-3}$.

- **BC (µg m$^{-3}$) - 1.68 m**
  - Mean values range from 1 to 2 µg m$^{-3}$.

- **UFP (N Particles cm$^{-3}$) - 0.80 m**
  - Mean values range from 16,000 to 24,000 N Particles cm$^{-3}$.

- **UFP (N Particles cm$^{-3}$) - 1.68 m**
  - Mean values range from 16,000 to 24,000 N Particles cm$^{-3}$.

- **PM$_{0.5}$ (µg m$^{-3}$) - 0.80 m**
  - Mean values range from 0.5 to 3.5 µg m$^{-3}$.

- **PM$_{0.5}$ (µg m$^{-3}$) - 1.68 m**
  - Mean values range from 0.5 to 3.5 µg m$^{-3}$.

- **PM$_{1}$ (µg m$^{-3}$) - 0.80 m**
  - Mean values range from 0.3 to 1 µg m$^{-3}$.

- **PM$_{1}$ (µg m$^{-3}$) - 1.68 m**
  - Mean values range from 0.3 to 1 µg m$^{-3}$.
Figure K16 Polar Plots of PM$_{2.5}$, PM$_{5.0}$, PM$_{10}$ and TPM – Sauchiehall St/Buchanan St

PM$_{2.5}$ ($\mu$g m$^{-3}$) - 0.80 m

PM$_{2.5}$ ($\mu$g m$^{-3}$) - 1.68 m

PM$_{5}$ ($\mu$g m$^{-3}$) - 0.80 m

PM$_{5}$ ($\mu$g m$^{-3}$) - 1.68 m

PM$_{10}$ ($\mu$g m$^{-3}$) - 0.80 m

PM$_{10}$ ($\mu$g m$^{-3}$) - 1.68 m

TPM ($\mu$g m$^{-3}$) - 0.80 m

TPM ($\mu$g m$^{-3}$) - 1.68 m
Figure K17 Polar Plots of NO\(_2\), NO, CO and SO\(_2\) – Sauchiehall St/Buchanan St

- NO\(_2\) (µg m\(^{-3}\)) - 0.80 m
- NO\(_2\) (µg m\(^{-3}\)) - 1.68 m
- NO (µg m\(^{-3}\)) - 0.80 m
- NO (µg m\(^{-3}\)) - 1.68 m
- CO (µg m\(^{-3}\)) - 0.80 m
- CO (µg m\(^{-3}\)) - 1.68 m
- SO\(_2\) (µg m\(^{-3}\)) - 0.80 m
- SO\(_2\) (µg m\(^{-3}\)) - 1.68 m
Figure K18 Polar Plots of BC, UFP, PM$_{0.5}$ and PM$_{1.0}$ – High St

BC ($\mu g m^{-3}$) - 0.80 m

BC ($\mu g m^{-3}$) - 1.68 m

UFP (N Particles cm$^{-3}$) - 0.80 m

UFP (N Particles cm$^{-3}$) - 1.68 m

PM$_{0.5}$ ($\mu g m^{-3}$) - 0.80 m

PM$_{0.5}$ ($\mu g m^{-3}$) - 1.68 m

PM$_{1}$ ($\mu g m^{-3}$) - 0.80 m

PM$_{1}$ ($\mu g m^{-3}$) - 1.68 m
Figure K19 Polar Plots of PM$_{2.5}$, PM$_{5.0}$, PM$_{10}$ and TPM – High St

PM$_{2.5}$ ($\mu$g m$^{-3}$) - 0.80 m

PM$_{5}$ ($\mu$g m$^{-3}$) - 0.80 m

PM$_{10}$ ($\mu$g m$^{-3}$) - 0.80 m

TPM ($\mu$g m$^{-3}$) - 0.80 m

PM$_{2.5}$ ($\mu$g m$^{-3}$) - 1.68 m

PM$_{5}$ ($\mu$g m$^{-3}$) - 1.68 m

PM$_{10}$ ($\mu$g m$^{-3}$) - 1.68 m

TPM ($\mu$g m$^{-3}$) - 1.68 m
Figure K20 Polar Plots of NO₂, NO, CO and SO₂ – High St

K1.5 Pollutant Concentrations vs Wind Speed and Direction
The following Figures show regression plots of particulate species and CO₂ vs wind speed and direction as recorded at Glasgow Airport.
Figure K21 One minute averaged data for particulate species and CO₂ vs. windspeed (m/s), as recorded at Glasgow Airport. Where UFP = ultrafine particles (units: N Particles cm⁻³); PM = particle mass (the figure refers to size in µm); TPM = total particulate mass (units: µg m⁻³); BC = Black Carbon (units: ng m⁻³); and CO₂ is Carbon Dioxide (units: ug m⁻³).
Figure K 22 Thirty minute averaged data for particulate species and CO₂ vs. windspeed (m/s), as recorded at Glasgow Airport.
Figure K23 One minute averaged data for particulate species and CO$_2$ vs. wind direction (°), as recorded at Glasgow Airport
Figure K24 Thirty minute averaged data for particulate species and CO₂ vs. wind direction (°), as recorded at Glasgow Airport

- 30 min average of UFP: $y = 7.593 + 241.62$, $R^2 = 0.0012$
- 30 min average of PM2.5: $y = -0.0112x + 14.637$, $R^2 = 0.0001$
- 30 min average of TPM: $y = -0.1278x + 82.432$, $R^2 = 0.0011$
- 30 min average of PM0.5: $y = 0.0035x + 1.5317$, $R^2 = 0.0217$
- 30 min average of PM5: $y = -0.0591x + 43.19$, $R^2 = 0.034$
- 30 min average of BC: $y = -1.377x + 4254.4$, $R^2 = 0.0009$
- 30 min average of PM1.0: $y = 0.0035x + 1.3821$, $R^2 = 0.0027$
- 30 min average of PM10: $y = -0.1074x + 70.579$, $R^2 = 0.0625$
- 30 min average of CO₂: $y = -0.0074x + 460.74$, $R^2 = 0.0001$