Upper Hunter
Air Quality Monitoring Network

2013 Annual Report

Acknowledgements

The following open-source statistical software was used in the data analysis for this report:

R:
R Development Core Team (2011), *R: A language and environment for statistical computing*, R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, http://www.R-project.org/.

Openair:
Carslaw, DC and Ropkins, K (2012), *openair – an R package for air quality data analysis*, *Environmental Modelling & Software*, vol. 27–28, pp. 52–61.

Satellite maps:
All satellite maps sourced from Google Earth ™ are dated 2008 approximately.

Weather maps:
All weather maps sourced from the Bureau of Meteorology website (www.bom.gov.au) from April to June 2014.

Williamtown upper air data:
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About this report

This is the second annual report on the Upper Hunter Air Quality Monitoring Network (UHAQMN). It covers the period from 1 January 2013 to 31 December 2013.

The data from the 14 stations in the network allow for a sufficiently robust assessment of regional air quality in the Upper Hunter, and after two full years of operation seasonal trends are apparent; however, a more comprehensive analysis of how the annual variation in weather conditions affects air quality will require further years of data.

This report describes the network performance for 2013 and provides some analysis of the air quality data gathered for the 12-month period to the end of December 2013.

Executive summary

The Upper Hunter Air Quality Monitoring Network (UHAQMN) was established to provide the community with information about levels of particles in the air, to aid in identifying emission sources, and, on a long-term basis, to inform regulatory programs that may be required if these emissions need to be reduced. Hourly air quality data from the network are presented on the Office of Environment and Heritage (OEH) website (www.environment.nsw.gov.au/aqms/uhunteraqmap.htm).

The 14 monitoring stations in the UHAQMN serve various purposes:

- **Air quality near larger population centres:** Singleton Central, Muswellbrook Central and Aberdeen
- **Air quality near smaller communities:** Bulga, Camberwell, Warkworth, Maison Dieu, Jerrys Plains and Wybong
- **Diagnostic information:** Mount Thorley, Singleton North West and Muswellbrook North West
- **Background air quality information:** Merriwa and Singleton South.

Monitors in the UHAQMN continuously measure particles (as PM_{10}), wind speed and wind direction at each of the monitoring sites, as well as finer particles (as $PM_{2.5}$) at Singleton, Muswellbrook and Camberwell, and sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) at Singleton and Muswellbrook.

This report provides a review of the UHAQMN for the 12-month period to 31 December 2013. The review includes a basic analysis of air quality compared with national standards, and a few case studies on processes impacting the regional air quality.

Days above benchmark concentrations

The Upper Hunter region experienced poorer air quality during 2013 compared to previous years, predominantly from increased bushfire activity during January and September–November. As a result, a large number of sites (especially within the Singleton LGA) exceeded the national standard for particles during these periods.

Details on days above the benchmark for PM_{10} are provided in Table 3 to Table 6, and for $PM_{2.5}$ in Table 7. A monthly breakdown is provided in Appendix 1.

Daily average PM_{10} and $PM_{2.5}$ levels and daily maximum hourly NO_2 and SO_2 levels are measured against benchmark values of 50 µg/m^3, 25 µg/m^3, 12 pphm and 20 pphm, respectively. Days above these national benchmarks during 2013 are outlined in Figure ES1, with daily calendar plots found in Appendix 2 to Appendix 5.

Of the major population centres, PM_{10} at Muswellbrook and Aberdeen, NO_2 and SO_2 at Singleton and Muswellbrook, and $PM_{2.5}$ at Singleton met the relevant annual National

Environment Protection Measure for Ambient Air Quality (Air NEPM) goals. Singleton did not meet the annual Air NEPM goal for PM_{10} as there were 12 days above the national standard of 50 $\mu g/m^3$. For $PM_{2.5}$, Muswellbrook experienced one day above the daily reporting standard of 25 $\mu g/m^3$ and exceeded the annual Air NEPM reporting standard of 8 $\mu g/m^3$.

$PM_{2.5}$ in Muswellbrook has a strong seasonal variation, with peak levels occurring in winter. The Upper Hunter Fine Particle Characterisation Study found that the highest contribution to annual $PM_{2.5}$ concentrations at Muswellbrook was smoke from domestic wood heaters (contributing around 30%). The study also found that wood heaters contributed around 14% of total annual $PM_{2.5}$ concentrations at Singleton. At both locations secondary sulphate (from local and regional sources of SO_2 such as power stations) and industry aged sea salt (sea salt combined with local and regional sources of SO_2, such as power stations) were major contributors to total annual $PM_{2.5}$ concentrations. More information about the study is available at www.environment.nsw.gov.au/aqms/uhaqmnfpcs.htm.

At the monitoring sites in smaller communities, PM_{10} levels above the benchmark concentration of 50 µg/m^3 were recorded at all stations, with the number of exceedence days as follows: Bulga (7), Camberwell (36), Jerrys Plains (6), Maison Dieu (28), Warkworth (8) and Wybong (2). For $PM_{2.5}$, Camberwell experienced one day above the benchmark of 25 $\mu g/m^3$ and annual levels were above the Air NEPM reporting standard of 8 µg/m^3.

At the diagnostic monitoring sites, PM_{10} levels at Muswellbrook NW, Mount Thorley and Singleton NW were above the benchmark concentration on 1, 26 and 28 days respectively.

At the background monitoring sites, PM_{10} levels did not exceed the benchmark at Merriwa, but did exceed the benchmark at Singleton South on five days during the October–November bushfires.

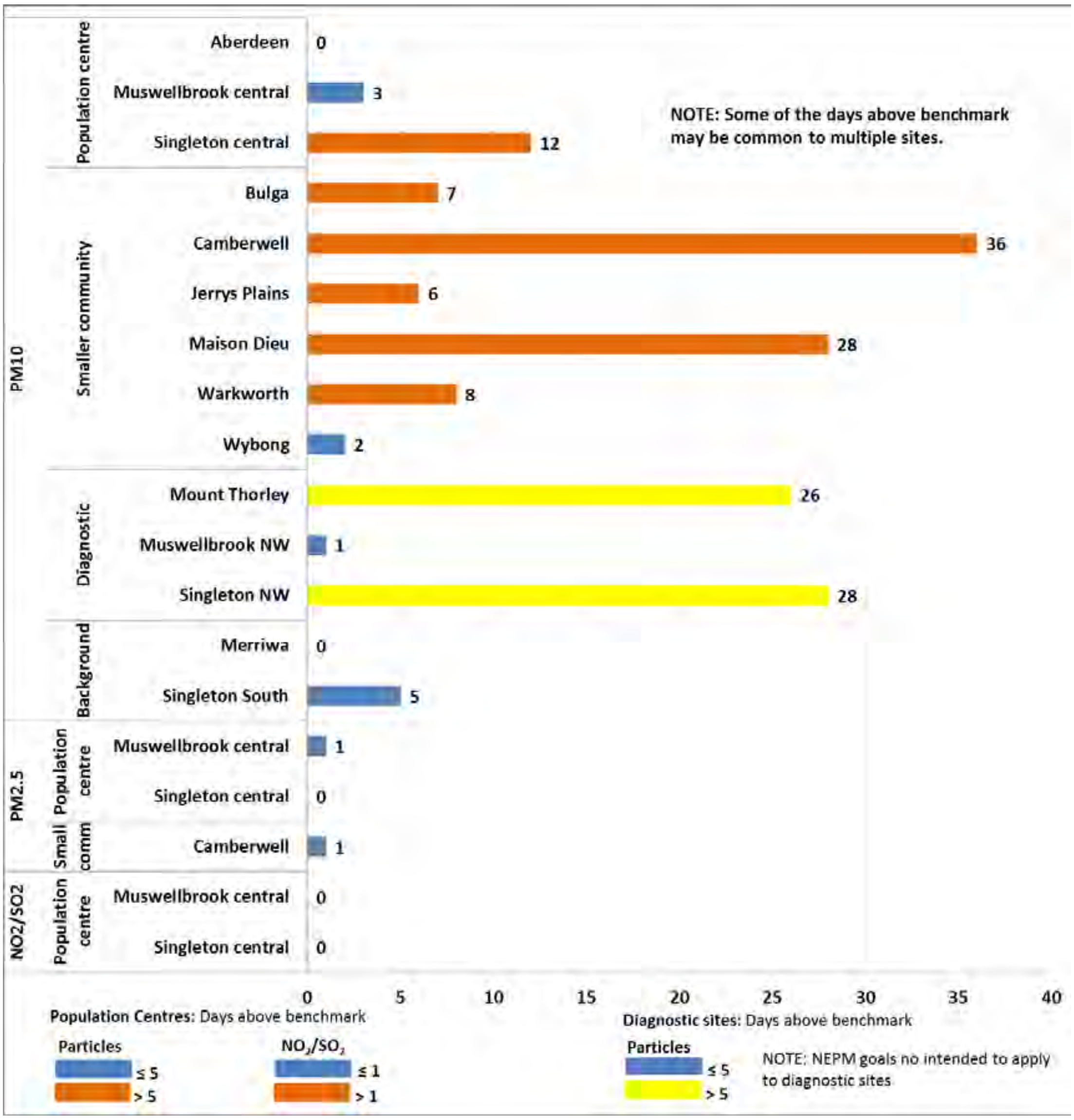


Figure ES1: Number of days above the PM_{10}, $PM_{2.5}$, NO_2 and SO_2 benchmark concentrations (1 January 2013 – 31 December 2013)

Online performance of the UHAQMN

An operational aim of the network is to achieve at least 95% valid data for all parameters measured over the year (allowing for maintenance and calibration). During 2013, the network met the 95% online requirement for most data at most monitoring stations, with the exceptions of NO_2 at Singleton (93%), $PM_{2.5}$ at Muswellbrook (92%) and Camberwell (92%), and wind at Singleton South (76%) and Merriwa (94%) (Table ES1).

Table ES1: Online performance of the UHAQMN (2013)

Site	PM_{10}	$PM_{2.5}$	Wind	NO_2 (1)	SO_2 (1)
Muswellbrook Central	✳✳✳✳	✳✳✳	✳✳✳✳	✳✳✳✳	✳✳✳✳
Singleton Central	✳✳✳✳	✳✳✳✳	✳✳✳✳	✳✳✳	✳✳✳✳
Maison Dieu	✳✳✳✳	NA	✳✳✳✳	NA	NA
Camberwell	✳✳✳✳	✳✳✳	✳✳✳✳	NA	NA
Mount Thorley	✳✳✳✳	NA	✳✳✳✳	NA	NA
Singleton NW	✳✳✳✳	NA	✳✳✳✳	NA	NA
Bulga	✳✳✳✳	NA	✳✳✳✳	NA	NA
Aberdeen	✳✳✳✳	NA	✳✳✳✳	NA	NA
Jerrys Plains	✳✳✳✳	NA	✳✳✳✳	NA	NA
Muswellbrook NW	✳✳✳✳	NA	✳✳✳✳	NA	NA
Singleton South	✳✳✳✳	NA	✳✳	NA	NA
Warkworth	✳✳✳✳	NA	✳✳✳✳	NA	NA
Wybong	✳✳✳✳	NA	✳✳✳✳	NA	NA
Merriwa	✳✳✳✳	NA	✳✳✳	NA	NA

(1) Gaseous monitors for NO_2 and SO_2 undergo daily calibrations, so the maximum online time is 96%.

Key

NA	Not applicable
✳✳✳✳	≥95% online
✳✳✳	90–94% online
✳✳	75–89% online
✳	<75% online

Webpage activity for the UHAQMN

For the map webpage (www.environment.nsw.gov.au/aqms/uhunteraqmap.htm), the number of page views for the period 1 January 2013 – 31 December 2013 is shown in Figure ES2.

During regular weeks the number of visits typically cycles between 0 and 40. During the bushfire events in September, October and November there were spikes in page views (174 on 10 September, 154 on 26 September, 227 on 21 October and a maximum of 230 on 23 October).

Figure ES2: Page views for the UHAQMN map webpage (2013)

The website, which is updated hourly, provides facilities for viewing Upper Hunter air quality data. Anyone visiting the website can view the hourly PM_{10}, $PM_{2.5}$, wind direction and wind speed data, create their own graphs of the hourly data, download historical data and compare Upper Hunter values to those for the rest of NSW.

SMS and email alerts

Aligned with OEH's main NSW Air Quality Monitoring Network (AQMN), to keep the community informed about air quality in the region, automatic SMS and email alerts are triggered by the UHAQMN when air quality is 'poor'. This is designed to allow those members of the community who may be susceptible to air pollution (e.g. asthmatics, people with heart disease) to receive these automatic alerts, helping then to take appropriate action to minimise their exposure.

OEH promotes this service via its website, through community meetings and communication with stakeholders, and through the media – subscribe to the alerts at www.environment.nsw.gov.au/aqms/subscribe.htm.

Numbers of subscribers to the UHAQMN alerts (as at 31 December 2013) are shown in Table ES2.

Table ES2: Numbers of subscribers to air quality alerts (as at 31 Dec 2013)

Subscription type	Site	Date online	Number of public subscribers
Email alerts	Muswellbrook Central	9/12/2010	150
	Singleton Central	9/12/2010	170
	Maison Dieu	1/04/2011	97
	Camberwell	25/07/2011	98
	Mt Thorley	25/07/2011	98
	Singleton NW	25/07/2011	125
	Bulga	12/08/2011	93
	Aberdeen	15/12/2011	75
	Jerrys Plains	15/12/2011	82
	Muswellbrook NW	15/12/2011	93
	Singleton South	15/12/2011	92
	Warkworth	15/12/2011	82
	Wybong	15/12/2011	73
	Merriwa	20/02/2012	71
SMS alerts	Muswellbrook Central	9/12/2010	71
	Singleton Central	9/12/2010	75
	Maison Dieu	1/04/2011	43
	Camberwell	25/07/2011	38
	Mt Thorley	25/07/2011	48
	Singleton NW	25/07/2011	56
	Bulga	12/08/2011	44
	Aberdeen	15/12/2011	34
	Jerrys Plains	15/12/2011	44
	Muswellbrook NW	15/12/2011	47
	Singleton South	15/12/2011	43
	Warkworth	15/12/2011	40
	Wybong	15/12/2011	32
	Merriwa	20/02/2012	30

large population centre

small population centre

diagnostic site

background site

NOTE: Alerts are provided when **rolling 24-hour averages** for PM_{10} or $PM_{2.5}$ concentrations are above the benchmark concentrations of 50 µg/m^3 and 25 µg/m^3 respectively.

1 About the Upper Hunter Air Quality Monitoring Network

1.1 What is the network?

The Upper Hunter Air Quality Monitoring Network (UHAQMN) is a high-quality, regional air quality monitoring network that continuously measures dust particles, meteorology and gases in the air. The network provides the community with hourly updates on current air quality in near real-time via the Office of Environment and Heritage (OEH) website.

The network consists of 14 monitoring stations linked to a central database. From here the data is uploaded hourly to the OEH website.

The network continuously measures:

- particles (as PM_{10}), wind speed, wind direction, temperature and humidity at all 14 monitoring sites
- finer particles (as $PM_{2.5}$) at Singleton, Muswellbrook and Camberwell, and
- the gases sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) at Singleton and Muswellbrook.

More information on the measurement techniques for PM_{10} and $PM_{2.5}$ are included in Appendix 6.

1.2 Who is responsible for the network?

The UHAQMN is a partnership between the NSW Government and the Upper Hunter coal and power industries. The sites are operated and maintained by OEH staff using funds contributed by industry under Chapter 5A of the Protection of the Environment (General) Regulation 2009.

The UHAQMN Advisory Committee advises the NSW Environment Protection Authority (EPA) and OEH on matters specifically related to the design and operation of the network. The Advisory Committee currently has 14 members representing the community, the coal and power generation industries, local government and NSW government agencies. More information about the committee is available at www.epa.nsw.gov.au/UHAQMCttee/index.htm.

1.3 What can the network tell us?

The network provides government, industry and the community with credible, reliable and up-to-date information about air quality and trends in air quality within the Upper Hunter Valley.

This information can be used to:

- assess changes in air quality
- help identify the major sources of the monitored pollutants, and
- inform regulatory programs in response to long-term trends.

Information from the network will help to guide specific investigations into the questions raised by the data, such as questions about the distribution of particles and the components making up the fine particle fraction of the particle mix. This information will assist NSW government agencies to develop further monitoring and compliance programs to improve Upper Hunter air quality.

1.4 Where are the monitoring stations located?

The locations of the UHAQMN sites are shown in Figure 1. Further site details are available at www.environment.nsw.gov.au/AQMS/sitesuh.htm.

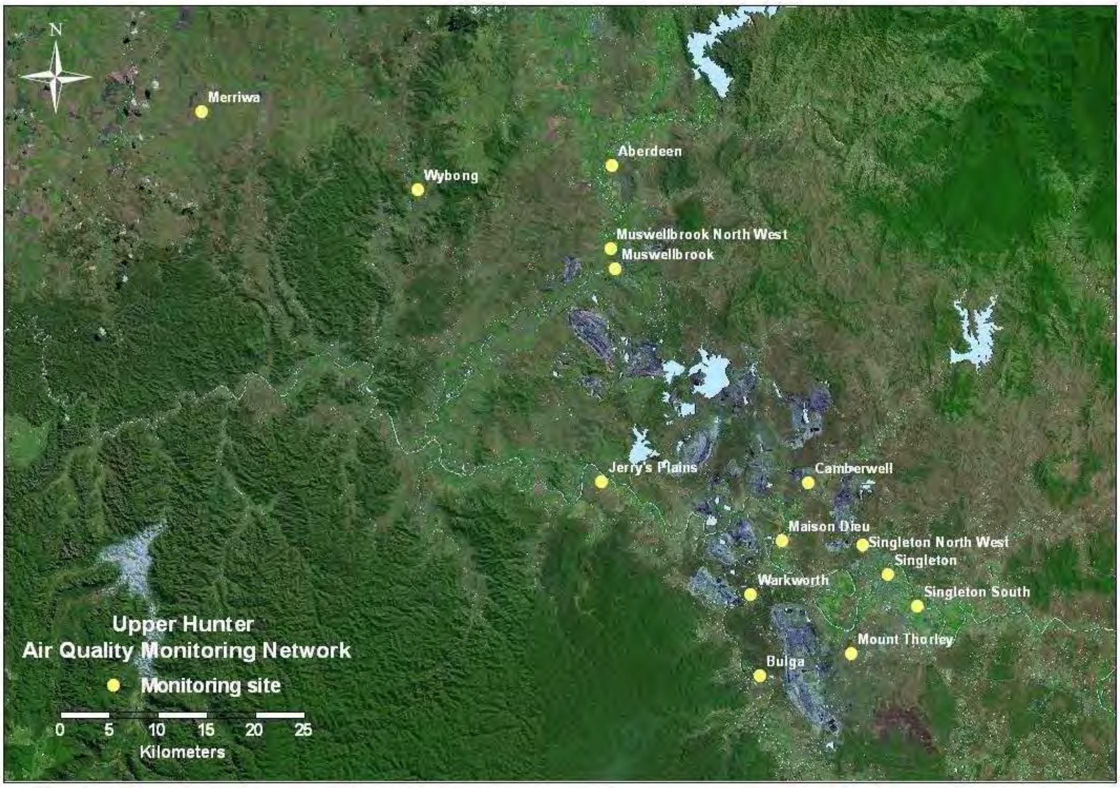


Figure 1: Monitoring station locations

1.5 Do all the monitoring stations serve the same purpose?

The monitoring network is based on a design developed by Holmes Air Sciences in 2008. The 14 monitoring stations serve different purposes (see Table 1):

- **Larger population centres:** the stations near the larger population centres monitor the air quality in these centres.
- **Smaller communities:** the stations located in smaller communities monitor the air quality at those locations.
- **Diagnostic:** these sites provide data that can help to diagnose the likely sources and movement of particles across the region as a whole; they do not provide information about air quality at population centres.
- **Background:** the stations near Merriwa and Singleton South are at both ends of the valley and provide background data, measuring the quality of air entering and leaving the Hunter Valley under predominant winds (south-easterlies and north-westerlies).

Table 1: Purposes of the monitoring stations in the UHAQMN

Purpose	Stations
Monitoring air quality in the larger population centres	Muswellbrook Central
	Singleton Central
	Aberdeen
Monitoring air quality in the smaller communities	Maison Dieu
	Camberwell
	Jerrys Plains
	Bulga
	Wybong
	Warkworth
Providing diagnostic data	Singleton NW
	Mount Thorley
	Muswellbrook NW
Providing background data	Singleton South
	Merriwa

The intention of the network design is that data gathered from the UHAQMN as a whole can be analysed to provide insights about Upper Hunter regional air quality and long-term trends in air quality.

1.6 How is the network performing?

The network maintained a high level of performance in 2013 (Table ES1) with valid and accurate data for more than 95% of all hours in the year at all PM_{10} and SO_2 monitoring sites and at the majority of sites for the remaining parameters. The sites/parameters that did not meet the 95% performance criteria were:

- $PM_{2.5}$ at Camberwell (92%) and Muswellbrook (92%)
- NO_2 at Singleton (93%), and
- wind at Merriwa (94%) and Singleton South (76%). Instrument faults at Singleton South affected the validity of the wind data at this site.

A network of complex scientific instruments requires regular maintenance and calibration. Maintenance and calibration schedules for the UHAQMN comply with the relevant Australian Standards for servicing the equipment to ensure that data provided to the community are accurate and timely. Maintenance and calibration tasks require approximately 5% of the network's running time. An operational aim of the network then, is to achieve at least 95% online time for all parameters measured.

Gaps in hourly data

Under national air quality guidelines and protocols, an 'average' is deemed valid only when at least 75% of data during the averaging period is valid. Therefore, a valid rolling 24-hour average or daily 24-hour average is only calculated when at least 18 valid hourly averages are available. As a consequence, where hourly data values are marked invalid, there may be periods when daily averages are not reported on the OEH website.

Gaps in data can be due to:

- **scheduled maintenance and calibration where the following are carried out on a regular basis:**

  For particles:
  - quarterly: clean sample head and inlet and replace filters; leak check (1–2 hours)
  - 6-monthly: flow audit (1–2 hours)
  - annual: software (1–2 hours) and hardware calibration (1–2 hours); zero stability check (at least 8 hours); site audit (1–2 hours)

  For NO_2/SO_2:
  - daily: overnight zero span calibration (1 hour)
  - monthly: replace filters (approx. 1 hour)
  - quarterly: clean sample head and inlet (approx. 1 hour)
  - 6 monthly: linearity check/calibration (2–3 hours)
- **equipment failure at site or communications failure between instrument and data logger (variable)**: data can be lost for either of these reasons – there will be gaps in the database and on the web

- **power outages at site (variable)**: data is lost as equipment is powered off during the outage
- **telecommunication problems (variable)**: data will not be loaded to the website during this period; however, the data is not lost but downloaded to the database and uploaded to the web once communication is re-established
- **website maintenance (variable)**: data is not lost because it is stored locally until the website is up and running again.

In spite of this potential for data loss, the network is maintaining close to or above the 95% benchmark for online performance for the majority of sites and parameters.

1.7 What are the national benchmarks for air quality?

The Australian benchmarks for air quality are set in the Ambient Air Quality National Environment Protection Measure (the Air NEPM). The Air NEPM defines the national ambient air quality standards and goals for various pollutants, including the concentration of particles (Table 2). For example, the daily average concentration of PM_{10} particles should not exceed 50 µg/m^3 on more than five days a year.

Table 2: Air NEPM standards and goals for dust particles, SO_2 and NO_2

Pollutant	How often is the average measured?	Benchmark (concentration)	Goal: how often can the concentration exceed this benchmark?
Particles as PM_{10}	Daily: 1 calendar day (24 hours)	50 µg/m^3	Maximum 5 days per year
Particles as $PM_{2.5}$	Daily: 1 calendar day (24 hours)	25 µg/m^3	The goal is to gather sufficient information to allow a standard to be set for $PM_{2.5}$ when the Air NEPM is reviewed. These benchmarks are an Australia-wide advisory reporting standard, in use until a standard has been set.
	Annual: 1 calendar year (12 months)	8 µg/m^3	
Sulfur dioxide (SO_2)(1)	Hourly	20 pphm	Maximum 1 day per year
	Daily: 1 calendar day (24 hours)	8 pphm	Maximum 1 day per year
	Annual: 1 calendar year (12 months)	2 pphm	Never
Nitrogen dioxide (NO_2)(1)	Hourly	12 pphm	Maximum 1 day per year
	Annual: 1 calendar year (12 months)	3 pphm	Never

(1) SO_2 and NO_2 are measured in parts per hundred million (pphm) where pphm = parts per hundred million by volume, i.e. parts of pollutant per hundred million parts of air.

1.8 How do these benchmarks apply to the Upper Hunter region?

For sites near larger population centres, air quality data can be compared against the relevant Air NEPM concentration values for PM_{10} (50 µg/m^3 averaged over 24 hours). Although there is no national goal for $PM_{2.5}$, data from the network can be compared to the advisory reporting standard of 25 µg/m^3 (averaged over 24 hours).

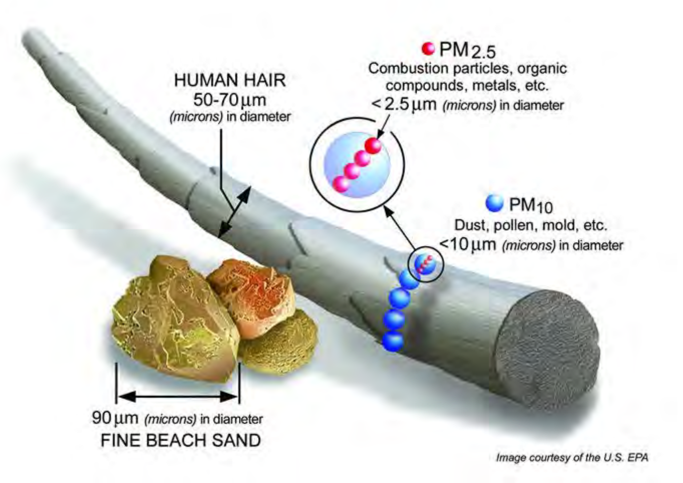
Measuring dust particles

Particle size (µm)

Particles are measured as:

- PM_{10} (particles 10 micrometres in diameter and smaller), and
- $PM_{2.5}$ (finer particles 2.5 micrometres in diameter and smaller).

1 micrometre (µm) = one millionth of a metre (also called a 'micron').



Particulate matter (reproduced with permission from the US EPA, Office of Research and Development)

Particle concentration (µg/m^3)

The concentration of dust particles in the air is measured as the mass of the particle in micrograms (µg) per volume of air in cubic metres (m^3).

1 microgram (µg) = one millionth of a gram.

The particle air quality benchmarks do not apply directly to the diagnostic monitoring sites (i.e. the monitoring stations that are located solely to enable diagnosis of dust sources). For example, the Singleton North West monitoring station measures the quality of air moving from the mining areas to the north-west towards Singleton.

Measurements of NO_2 and SO_2 (at Muswellbrook Central and Singleton Central) can be compared to the national benchmarks for these pollutants (Table 2).

2 Upper Hunter air quality during 2013

2.1 PM_{10} monitoring data

Smoke from large scale bushfires during January and September–November contributed to increased particle pollution on many days at many sites in the region.

PM_{10} in larger population centres

The Air NEPM goal for PM_{10} is for no more than five days to exceed the benchmark in a 12-month period. Table 3 shows sites, days, time of day of elevated hourly concentrations and associated daily meteorological conditions during the reporting period where the daily average PM_{10} exceeded the 50 µg/m^3 benchmark at the larger population centres. Muswellbrook Central and Aberdeen monitoring sites achieved the Air NEPM goal during 2013 (Figure 2).

In summary, at each of the larger population sites:

- Daily average PM_{10} levels at Aberdeen were below 50 µg/m^3 throughout 2013.
- Daily average PM_{10} levels at Muswellbrook Central were less than the 50 µg/m^3 benchmark throughout the reporting period except for three days later in the year. Winds on these days were generally light and variable (see Table 3). This is two more exceedence days than were experienced in 2012.
- Daily average PM_{10} levels at Singleton Central were above the 50 µg/m^3 benchmark on 12 days within the reporting period, therefore not meeting the Air NEPM goal. This is six more exceedence days than were experienced in 2012. See Table 3 for details on PM_{10} concentrations and meteorological conditions for these days.

Table 3: Larger population centres – days above the PM_{10} benchmark (2013)

Station	Daily average concentration (µg/m^3)	Date	Comments (including daytime temperatures, time of elevated hourly values and associated winds)
Muswellbrook Central	52.2	01/09/2013	Mild, early morning, very light variable winds
	55.6	29/10/2013	Warm, morning, very light variable winds, bushfires
	54.3	08/11/2013	Hot, early morning and late night, mainly light E to S winds, bushfires
Singleton Central	54.5	08/01/2013	Very hot, throughout, moderate NW winds
	58.6	09/01/2013	Hot, until late afternoon, moderate NW then ESE from late morning, bushfires
continued…	51.2	18/01/2013	Very hot, from mid-morning, moderate NW winds, bushfires

Table 3 continued

Station	Daily average concentration (µg/m^3)	Date	Comments (including daytime temperatures, time of elevated hourly values and associated winds)
Singleton Central cont.	53.3	06/09/2013	Warm, throughout, light NW winds then SE in the evening
	59.5	10/09/2013	Warm, from mid-morning, fresh NW winds
	58.4	10/10/2013	Hot, throughout, very light variable winds in the morning then moderate to fresh NW, bushfires
	57.9	13/10/2013	Hot, throughout, peak at midday under moderate to fresh NW winds, bushfires
	62.7	17/10/2013	Hot, mainly during daytime under moderate to fresh NW, bushfires
	57.3	22/10/2013	Hot, throughout, mainly under light SE winds, bushfires
	53.5	03/11/2013	Hot, throughout, variable winds, bushfires
	52.2	08/11/2013	Hot, mid to late morning and night under variable winds, bushfires
	51.4	23/12/2013	Hot, mid to late morning under light to moderate NW winds, then late night under light W to SE winds

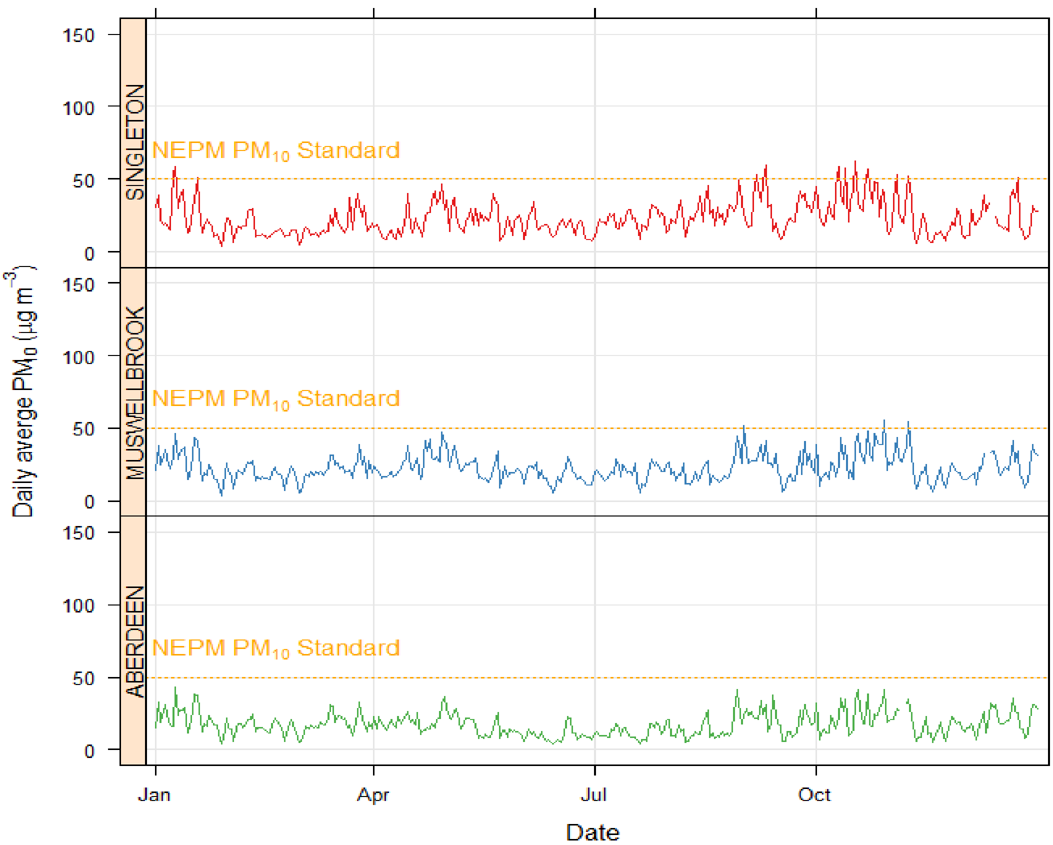


Figure 2: Larger population centres – daily average PM_{10} levels (2013)

PM_{10} in smaller communities

Daily average PM_{10} levels at all smaller community sites were above the 50 µg/m^3 during 2013, with the number of exceedence days as follows: Bulga (7), Camberwell (36), Jerrys Plains (6), Maison Dieu (28), Warkworth (8) and Wybong (2) (Figure 3). This is an increase in exceedences compared to 2012, when the highest number at the smaller community sites was 23 days (at Camberwell).

Table 4 lists the sites, days, times of elevated concentrations and associated daily meteorological conditions during the 2013 reporting period where the daily average PM_{10} exceeded the 50 µg/m^3 benchmark.

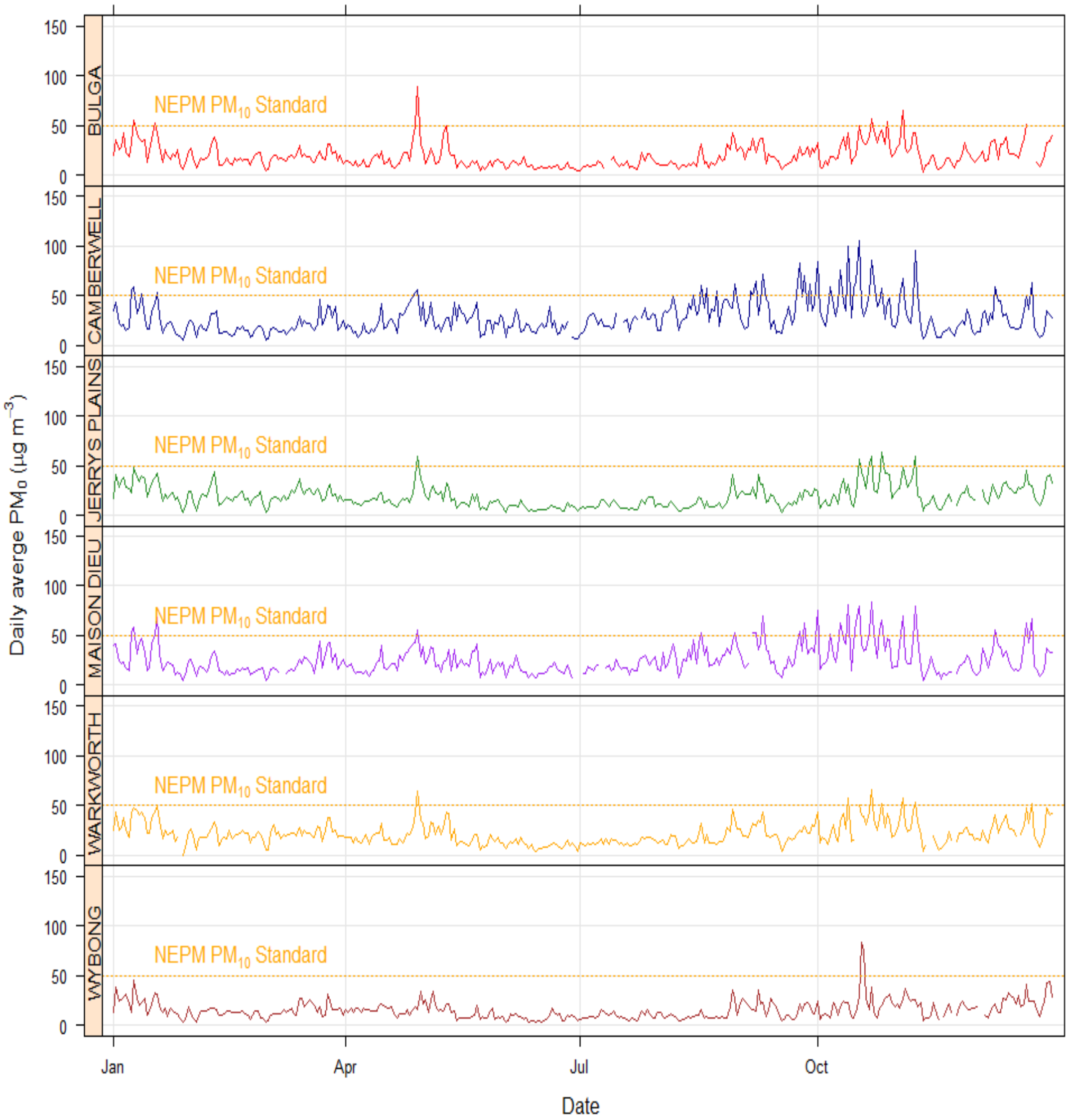


Figure 3: Smaller communities – daily average PM_{10} levels (2013)

Table 4: Smaller communities – days above the PM_{10} benchmark (2013)

Station	Daily average concentration (µg/m^3)	Date	Comments (including daytime temperatures, time of elevated hourly values and associated winds)
Bulga	55.0	09/01/2013	Hot, from late morning, moderate ESE winds, bushfires
	53.0	17/01/2013	Very hot, from late morning, light E to SE winds, bushfires
	88.4	29/04/2013	Warm, particularly from mid-morning, light NW through to E winds
	56.3	22/10/2013	Hot, from mid-morning, light S to E winds, bushfires
	53.3	28/10/2013	Warm, from mid-afternoon, light NW to SE winds, bushfires
	64.3	03/11/2013	Hot, throughout, very light variable winds in morning then moderate W, bushfires
	50.5	21/12/2013	Hot, from midday, light E winds
Camberwell	55.1	08/01/2013	Very hot, morning under light WNW winds, then night under fresh NW winds
	58.0	09/01/2013	Hot, throughout until late afternoon, moderate to fresh NW then ESE winds, bushfires
	51.0	12/01/2013	Very hot, morning under light WNW winds, then evening under light NW to ESE winds, bushfires
	53.3	18/01/2013	Very hot, from mid-morning, mainly under light to moderate NW winds, bushfires
	52.9	28/04/2013	Warm, throughout, light variable winds
	55.5	29/04/2013	Warm, throughout, light variable winds
	50.1	14/08/2013	Mild, throughout, light W to NW winds
	59.6	17/08/2013	Mild, before midday, light variable winds
	56.7	19/08/2013	Mild, mainly during day, moderate to fresh WNW winds
	53.9	23/08/2013	Cool, throughout, light to fresh WNW winds
	61.9	30/08/2013	Warm, morning under light E to S winds then from evening under light NW winds
	54.4	05/09/2013	Warm, night, light NW winds
	50.6	06/09/2013	Warm, throughout, mainly light NW winds
	63.7	07/09/2013	Warm, throughout, light ENE to NW winds
	71.7	10/09/2013	Warm, throughout, light to fresh W to NW winds
	51.2	23/09/2013	Warm, mainly at night, light WNW to E winds
	82.9	24/09/2013	Warm, throughout, mainly light E winds in morning then moderate W to NW
	70.0	26/09/2013	Hot, throughout, highest in middle of day under fresh W–NW winds
	62.1	28/09/2013	Warm, throughout, light to fresh NW winds
	84.0	01/10/2013	Hot, up to mid-afternoon, light E winds then fresh NW
	58.3	06/10/2013	Hot, morning under light WNW winds then night under light N to NW winds
continued…	74.9	10/10/2013	Hot, throughout, light W to NW then fresh NW to NNW winds

Table 4 continued

Station	Daily average concentration ($\mu g/m^3$)	Date	Comments (including daytime temperatures, time of elevated hourly values and associated winds)
Camberwell continued	99.3	13/10/2013	Hot, throughout, mainly light to fresh NW winds, bushfires
	56.8	15/10/2013	Mild, throughout, light E then NW winds, bushfires
	62.3	16/10/2013	Warm, throughout, highest peaks at night under light N winds, bushfires
	104.8	17/10/2013	Hot, throughout day, light variable then moderate to fresh NW, bushfires
	51.1	21/10/2013	Hot, throughout, light NW with highest peak at night under light E winds, bushfires
	85.2	22/10/2013	Hot, throughout, variable winds, bushfires
	65.3	23/10/2013	Hot, throughout, mainly light to fresh NW winds, bushfires
	57.5	26/10/2013	Warm, mainly during day, light NW then E winds, bushfires
	66.3	03/11/2013	Hot, throughout, mainly light to fresh NW to W, bushfires
	94.7	08/11/2013	Hot, morning under light ENE then night under light NW to SW winds, bushfires
	53.0	09/11/2013	Hot, throughout, mainly light to fresh W to NW winds, bushfires
	58.5	09/12/2013	Hot, morning under light E to NW then night under moderate to fresh NW winds
	50.4	21/12/2013	Hot, until mid-afternoon, light NW turning through to SE winds
	62.5	23/12/2013	Hot, throughout, mainly light to moderate NW winds
Jerrys Plains	58.6	29/04/2013	Warm, throughout, light WSW then E winds
	56.1	17/10/2013	Hot, throughout, fresh NW with peaks at night under W winds, bushfires
	52.2	21/10/2013	Hot, morning, light W winds, bushfires
	59.4	22/10/2013	Hot, throughout, light WSW then moderate SE winds, bushfires
	63.3	26/10/2013	Warm, during day, light NW then SE winds, bushfires
	58.7	08/11/2013	Hot, morning under light W then at night under light NW to SW winds, bushfires
Maison Dieu	52.2	08/01/2013	Very hot, throughout, moderate to fresh NNW winds
	58.8	09/01/2013	Hot, up to mid-afternoon, moderate to fresh W to NW then ESE winds , bushfires
	50.8	17/01/2013	Very hot, throughout, variable but generally SE winds, bushfires
	68.5	18/01/2013	Very hot, from mid-morning, mainly moderate to fresh NW winds then variable at night, bushfires
	55.1	29/04/2013	Warm, throughout, light NE to NW then S winds
	52.6	17/08/2013	Mild, morning, mainly light NE winds
	53.4	30/08/2013	Warm, throughout, mainly light NE winds
	53.0	06/09/2013	Warm, throughout, light NE then SE winds
continued…	52.3	07/09/2013	Warm, morning under light NE then night under NE to SSE winds

Table 4 continued

Station	Daily average concentration ($\mu g/m^3$)	Date	Comments (including daytime temperatures, time of elevated hourly values and associated winds)
Maison Dieu continued	69.0	10/09/2013	Warm, throughout, moderate to fresh NW winds
	54.3	24/09/2013	Warm, until mid-afternoon, light NE then fresh NW winds
	62.9	26/09/2013	Hot, throughout, light NE then moderate to strong WNW
	75.8	01/10/2013	Hot, until mid-afternoon, light NE then moderate to strong NW winds
	51.5	06/10/2013	Hot, morning under light NE then night under N to NE winds
	62.5	10/10/2013	Hot, throughout, moderate to fresh NNW to WNW winds, bushfires
	80.9	13/10/2013	Hot, throughout, mainly moderate to fresh NW winds, bushfires
	64.2	16/10/2013	Warm, throughout, light NE to moderate NW winds, bushfires
	79.8	17/10/2013	Hot, up to evening, mainly moderate to strong NW winds, bushfires
	54.5	21/10/2013	Hot, throughout, light NE to moderate NW winds, bushfires
	84.2	22/10/2013	Hot, throughout, light NE to S to SE winds, bushfires
	52.6	23/10/2013	Hot, throughout, light N to strong W to NW winds, bushfires
	56.2	25/10/2013	Mild, throughout, variable winds, bushfires
	65.6	26/10/2013	Warm, mainly during day, light NE to NW then fresh E winds, bushfires
	69.7	03/11/2013	Hot, throughout, light NE to fresh W to NW then SE winds, bushfires
	79.9	08/11/2013	Hot, throughout, light NE to moderate NW then variable winds, bushfires
	55.4	09/12/2013	Hot, throughout, light NE to moderate NW winds
	62.1	21/12/2013	Hot, until mid-afternoon, variable winds
	66.5	23/12/2013	Hot, throughout, mainly moderate to fresh NW winds with night peak under E winds
Warkworth	65.0	29/04/2013	Warm, throughout, light SE to SW to NW winds
	57.7	13/10/2013	Hot, throughout, moderate to fresh NW winds, bushfires
	50.5	17/10/2013	Hot, mainly during day, moderate NW to SW winds, bushfires
	65.4	22/10/2013	Hot, throughout, mainly light E to SE winds, bushfires
	52.5	26/10/2013	Warm, during day, light NNW to E winds, bushfires
	57.9	03/11/2013	Hot, throughout, mainly light W to NNW winds, bushfires
	54.1	08/11/2013	Hot, throughout, light S to NNW winds, bushfires
	51.9	23/12/2013	Hot, throughout, moderate to fresh NW with peaks at night under SE winds
Wybong	83.0	18/10/2013	Cool, throughout, light SE winds, bushfires
	75.1	19/10/2013	Warm, mainly from midday, light SE to S winds, bushfires

PM_{10} at diagnostic sites

The diagnostic sites, operating close to existing mines, are intended to provide information on trends and likely sources of dust to assist in the interpretation of elevated particle levels in population centres.

For the Muswellbrook NW site there was one day above the 50 µg/m³ PM_{10} benchmark, while for Singleton NW and Mount Thorley there were 28 and 26 days respectively above this benchmark (Figure 4). This is similar to 2012, when there were 29 and 26 days over the benchmark at Singleton NW and Mount Thorley, respectively.

Table 5 lists the exceedence days and provides information on the governing weather conditions on these days.

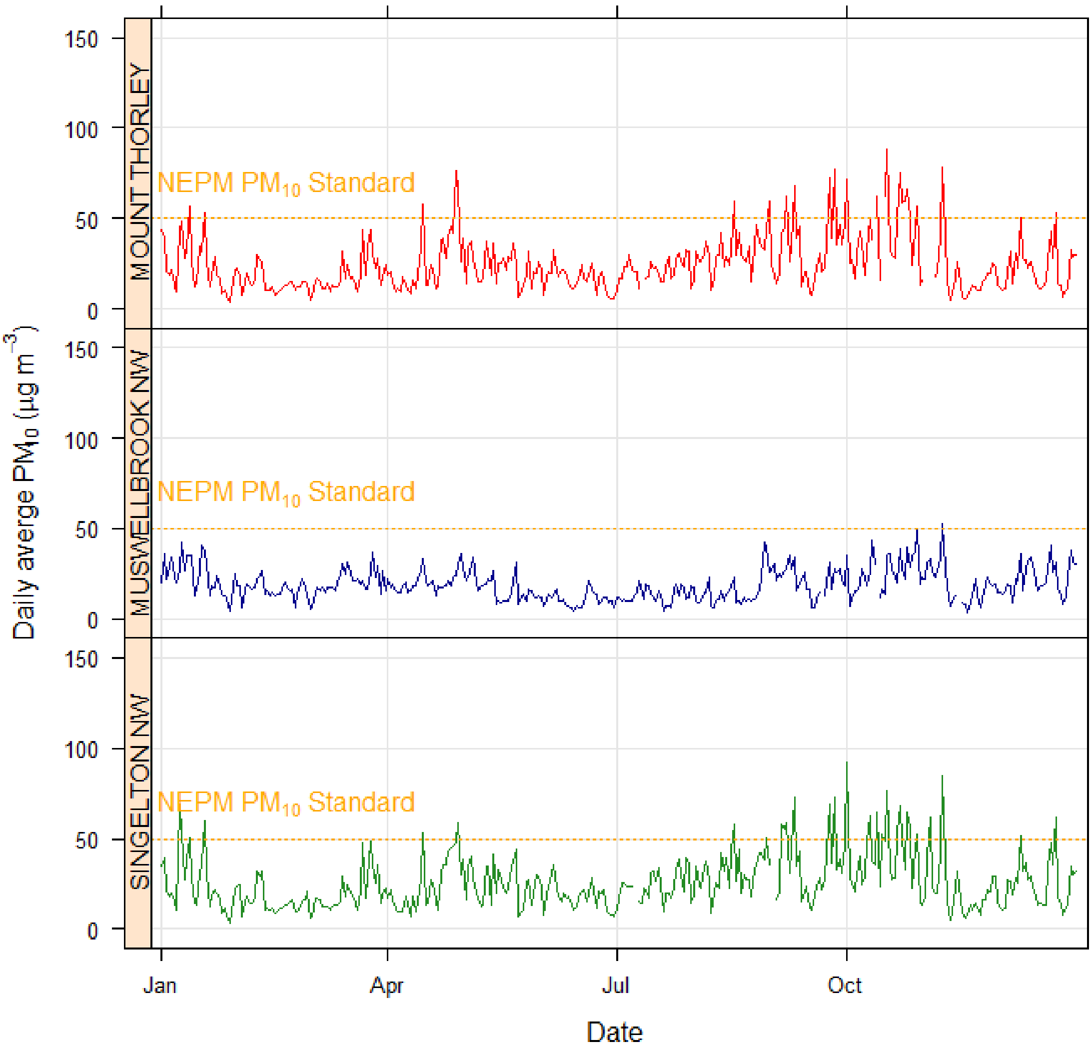


Figure 4: Diagnostic sites – daily average PM_{10} levels (2013)

Table 5: Diagnostic sites – days above the PM_{10} benchmark (2013)

Station	Daily average concentration (µg/m^3)	Date	Comments (including daytime temperatures, time of elevated hourly values and associated winds)
Mount Thorley	56.6	12/01/2013	Very hot, morning under light NE to moderate NW then evening peak under moderate E winds, bushfires
	53.5	18/01/2013	Very hot, from mid-morning, moderate to fresh N to NW then night peaks under S winds, bushfires
	58.2	15/04/2013	Warm, morning, light S to E then N to NE winds
	76.1	28/04/2013	Warm, throughout, light S to NW winds
	67.4	29/04/2013	Warm, throughout, light S to NW then SE winds
	59.7	17/08/2013	Mild, mainly morning, light variable S to NE then moderate NW winds
	59.3	31/08/2013	Warm, morning, light variable winds
	62.7	07/09/2013	Warm, morning and night, light and variable S to NE winds
	67.8	10/09/2013	Warm, throughout, moderate to fresh NW then SW winds
	72.9	24/09/2013	Warm, throughout, light S to SE then light to fresh NW winds
	77.6	26/09/2013	Hot, throughout, light S to E then light to strong W to NW winds
	71.8	01/10/2013	Hot, up to mid-afternoon, light SE then light to strong NW winds
	50.2	10/10/2013	Hot, throughout, light to fresh NW to SW winds, bushfires
	62.9	13/10/2013	Hot, throughout, light variable NE to S then moderate to fresh NW winds, bushfires
	62.4	16/10/2013	Warm, morning and night, light and variable S to NE winds, bushfires
	88.3	17/10/2013	Hot, until evening, light variable then moderate to strong NW to SW winds, bushfires
	50.6	21/10/2013	Hot, morning, light variable S to NE then moderate N to NW winds, bushfires
	75.3	22/10/2013	Hot, mainly morning, light S to SE winds, bushfires
	59.1	23/10/2013	Hot, throughout, light variable then fresh NW to SW winds, bushfires
	59.8	24/10/2013	Mild, up to late afternoon, light variable then moderate NW to SW winds, bushfires
	66.4	25/10/2013	Mild, throughout, light SSW then NW to N winds, bushfires
	50.1	26/10/2013	Warm, up to evening, light variable winds, bushfires
	57.1	29/10/2013	Warm, up to early afternoon, light S then moderate N to NW winds, bushfires
	78.3	08/11/2013	Hot, throughout, light S then NE to NW winds, bushfires
	50.5	09/12/2013	Hot, throughout, light S then N to NW winds
	53.4	23/12/2013	Hot, from mid-morning, moderate NW to S winds

Table 5 continued

Station	Daily average concentration (μg/m³)	Date	Comments (including daytime temperatures, time of elevated hourly values and associated winds)
Muswellbrook NW	52.4	08/11/2013	Hot, morning under light variable winds then night under NW to WSW winds, bushfires
Singleton NW	68.6	08/01/2013	Very hot, throughout, light to moderate WNW to NNW winds
	54.2	09/01/2013	Hot, to mid-afternoon, moderate NW to W then SE winds, bushfires
	50.5	12/01/2013	Very hot, morning under light NW to W then evening peak under SE winds
	60.0	18/01/2013	Very hot, from mid-morning, mainly light to moderate NW, bushfires
	52.9	15/04/2013	Warm, morning, light NW winds
	58.9	29/04/2013	Warm, morning under light NW then night under light SE winds
	57.7	17/08/2013	Mild, to early afternoon, light variable winds
	50.2	30/08/2013	Warm, throughout, light variable then NW winds
	57.6	05/09/2013	Warm, throughout, light WNW to NNW winds
	55.2	06/09/2013	Warm, throughout, light NW then SE winds
	58.9	07/09/2013	Warm, throughout, mainly light NW winds
	73.1	10/09/2013	Warm, throughout, light to fresh W to NW winds
	69.1	24/09/2013	Warm, to mid-afternoon, mainly light to moderate NW to W winds
	73.2	26/09/2013	Hot, to mid-afternoon, light to fresh NW to WNW winds
	91.7	01/10/2013	Hot, to mid-afternoon, light to fresh NW to W winds
	62.4	10/10/2013	Hot, throughout, light to fresh W to NNW winds, bushfires
	64.1	13/10/2013	Hot, throughout, light to moderate WNW to NNW winds, bushfires
	52.6	15/10/2013	Mild, morning and night, light NW winds, bushfires
	76.0	17/10/2013	Hot, to evening, light to fresh WSW to NW winds, bushfires
	53.4	21/10/2013	Hot, morning and night, light NW winds, bushfires
	67.8	22/10/2013	Hot, throughout, light NW then SW winds, bushfires
	64.1	25/10/2013	Mild, throughout, light varying from SW to NW winds, bushfires
	56.1	26/10/2013	Warm, to evening, light NW then NE to SE winds, bushfires
	52.3	29/10/2013	Warm, morning, light NW winds, bushfires
	61.5	03/11/2013	Hot, mainly morning, light NW winds, bushfires
	85.0	08/11/2013	Hot, morning and night, light NNW to SW winds, bushfires
	51.7	09/12/2013	Hot, morning and night, mainly light NW winds
	61.5	23/12/2013	Hot, throughout, mainly light to fresh NW winds

PM_{10} at background sites

Background monitoring sites were placed at the northern and southern ends of the Upper Hunter Valley (Merriwa and Singleton South) to provide information on levels of particles in air travelling into and out of the valley.

The daily PM_{10} benchmark of 50 $\mu g/m^3$ was not exceeded at Merriwa during 2013; however, it was exceeded on five days (four in October and one in November) at Singleton South (Figure 5 and Table 6).

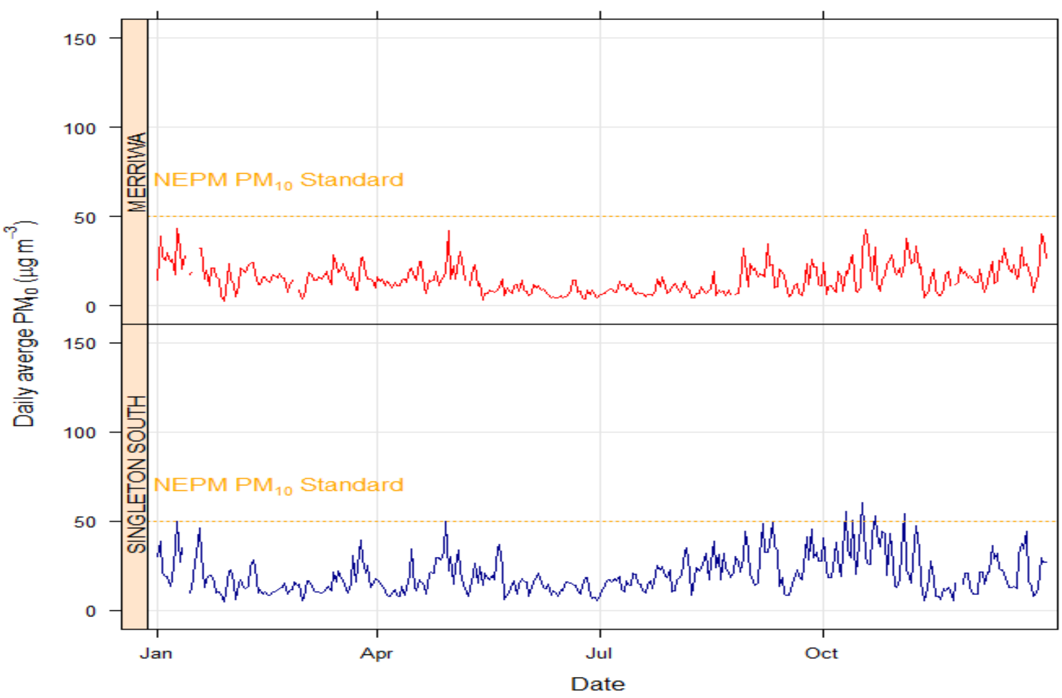


Figure 5: Background sites – daily average PM_{10} levels (2013)

Table 6: Background sites – days above the PM_{10} benchmark (2013)

Station	Daily average concentration ($\mu g/m^3$)	Date	Comments (including daytime temperatures, time of elevated hourly values and associated winds)
Singleton South	55.4	10/10/2013	Hot, throughout, light to fresh NW to SSE winds, bushfires
	50.5	13/10/2013	Hot, from mid-morning, mainly moderate to strong NW winds, bushfires
	60.3	17/10/2013	Hot, to evening, light variable then strong NW to SW winds, bushfires
	53.0	22/10/2013	Hot, throughout, mainly light to moderate E to SE winds, bushfires
	54.0	03/11/2013	Hot, morning under light to moderate NNW to SW then evening peak under moderate SE winds, bushfires

Summary – PM_{10} monitoring in 2013

Smoke from large scale bushfires during January and September–November contributed to increased particle pollution on many days and at many sites in the region.

- **Larger population centres**

  Singleton Central did not comply with the Air NEPM goal for 24-hour PM_{10} (fewer than 5 days above 50 µg/m^3) during 2013. The 12 exceedence days at Singleton Central coincided with exceedence days at Camberwell, Maison Dieu and Singleton NW plus other sites on individual days (Appendix 1 – Table 12). These events occurred during the warmer months (January and September–December) and were most often associated with light variable winds or down valley (north-westerly) winds. Levels were also affected by increased bushfire activity during January and the September to November bushfire period (see Table 10 for more information).

  Overall, the larger population centres had fewer exceedences than smaller communities within the centre of the Upper Hunter Valley.

- **Smaller community sites**

  As in 2012, Camberwell and Maison Dieu recorded the highest frequency of days above the PM_{10} benchmark (36 and 28 days respectively). The majority of these events occurred in the warmer months, in particular during the spring season. These were often associated with north-westerly winds at Camberwell and north-east to north-westerly winds for Maison Dieu; however, elevated levels were also experienced at these sites when winds were from various other directions.

- **Diagnostic sites**

  As in 2012, Singleton NW and Mount Thorley had the highest frequency of days above the PM_{10} benchmark (28 and 26 days respectively). The majority of these events were observed in the warmer months, in particular during the spring season. These were most often associated with north-westerly winds for Singleton NW and southerly or north-westerly winds for Mt Thorley; however, on some occasions elevated levels were also experienced at these sites when winds were from various other directions.

- **Background sites**

  At the background monitoring sites, PM_{10} levels did not exceed the benchmark at Merriwa, but did exceed the benchmark at Singleton South on five days during the October–November bushfires.

PM_{10} at Camberwell

The Camberwell station (a smaller population site) (Figure 6) recorded daily PM_{10} averages above the benchmark on 36 days in 2013 (Figure 7), the highest number of exceedences at any site within the region during the reporting period (Figure ES1). For comparative purposes, although there were fewer PM_{10} exceedences at Camberwell in 2012 (23 days in total), Figure 8 shows that the higher PM_{10} days occurred during the same periods in both years.

The majority of the exceedence days (75%) were experienced from mid-August to early November. During the earlier part of this period (mid-August to early September) temperatures were mild to warm and conditions were dry. Following a rain event mid-September, temperatures then became predominantly hot and conditions dry during the period of high PM_{10} levels (with no significant rainfall other than one rain event at the end of October). Levels were also affected by increased bushfire activity during January and the September to November bushfire period.

Camberwell is surrounded by coal mines in most directions with the closest mine extending from the north-east to north-west (Figure 6). Figure 9 and Figure 10 indicate that highest levels of PM_{10} (> 150 µg/m^3) were predominantly associated with strong winds from the north-west during the daytime.

Figure 6: Camberwell monitoring site location

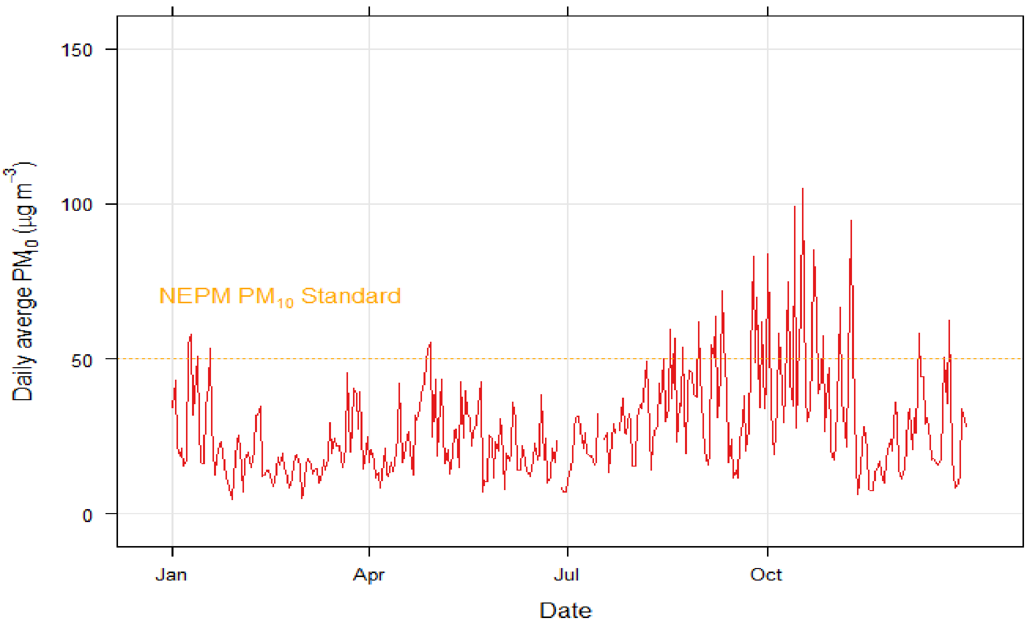


Figure 7: Camberwell – daily average PM_{10} levels (2013)

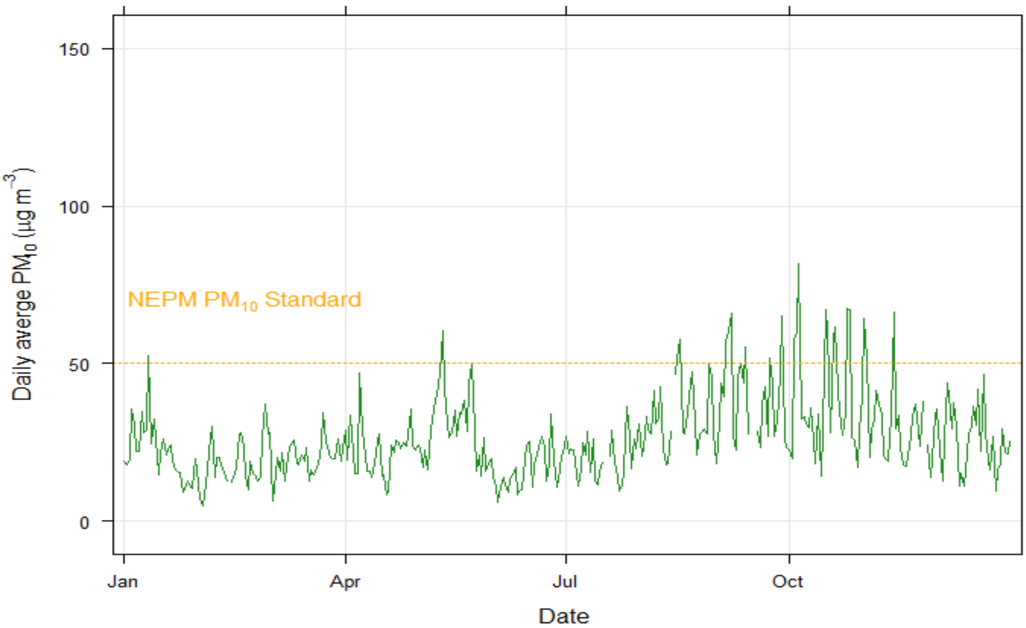


Figure 8: Camberwell – daily average PM_{10} levels (2012)

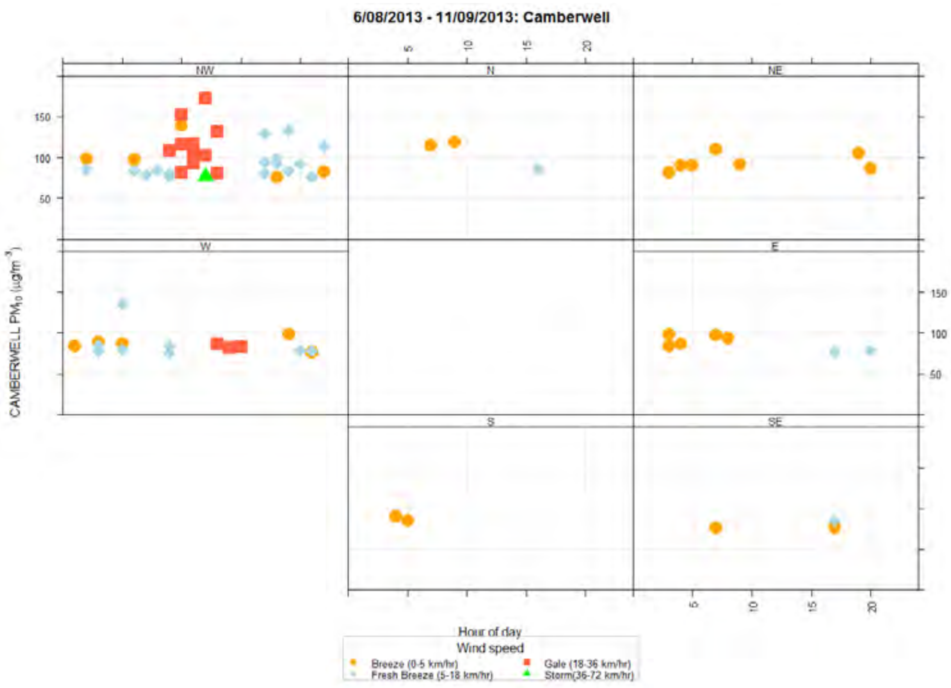


Figure 9: Camberwell – hourly average PM_{10} levels and wind conditions (6 August – 11 September 2013)

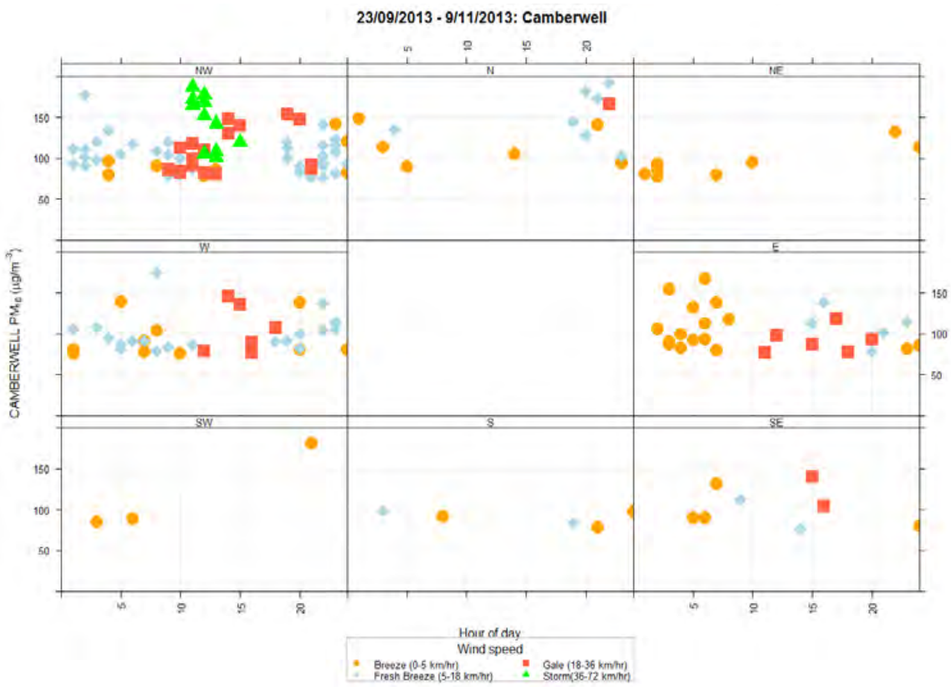


Figure 10: Camberwell – hourly average PM_{10} levels and wind conditions (23 September – 9 November 2013)

Figure 11 is a plot of the number of hours above 75 μg/m^3 during 2013 categorised by wind direction[1]. It shows that the greater proportion of hourly PM_{10} values above 75 μg/m^3 are associated with winds from west to north-west.

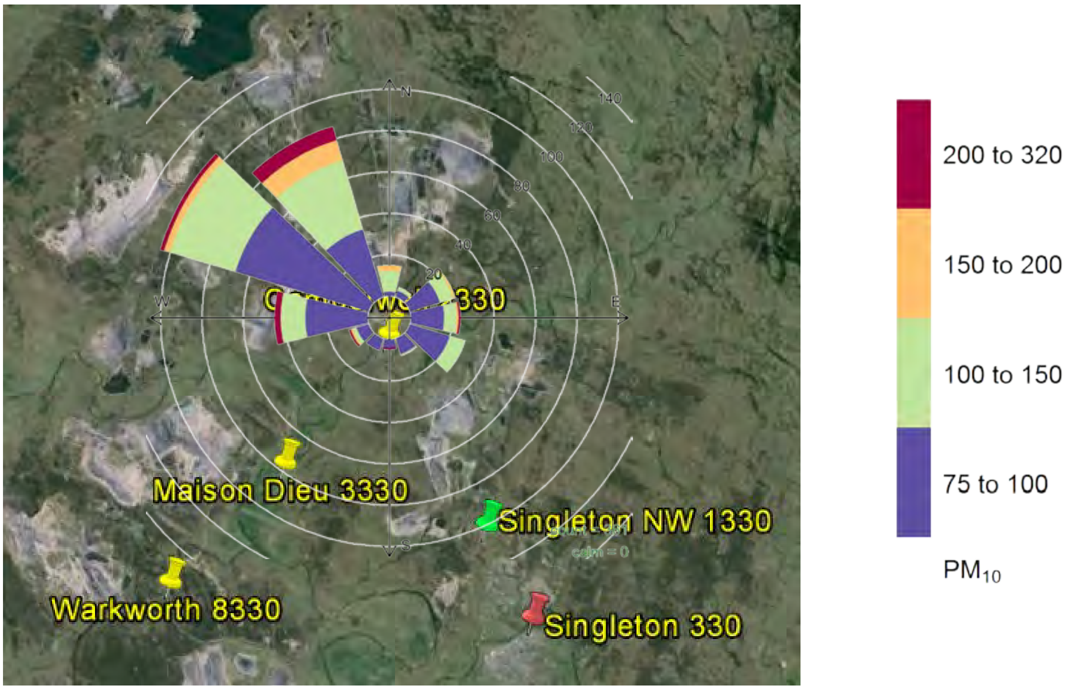


Figure 11: Camberwell pollution rose – counts of hourly average PM_{10} levels >75 μg/m^3 by wind direction (2013)

The seasonal breakdown in Figure 12 shows that although these elevated levels occur throughout the year, the highest levels were experienced during spring.

[1] Note: 75 μg/m^3 was chosen as a lower cut-off point to highlight only those hours with relatively elevated hourly PM_{10} levels. There is no Air NEPM standard for hourly PM_{10}.

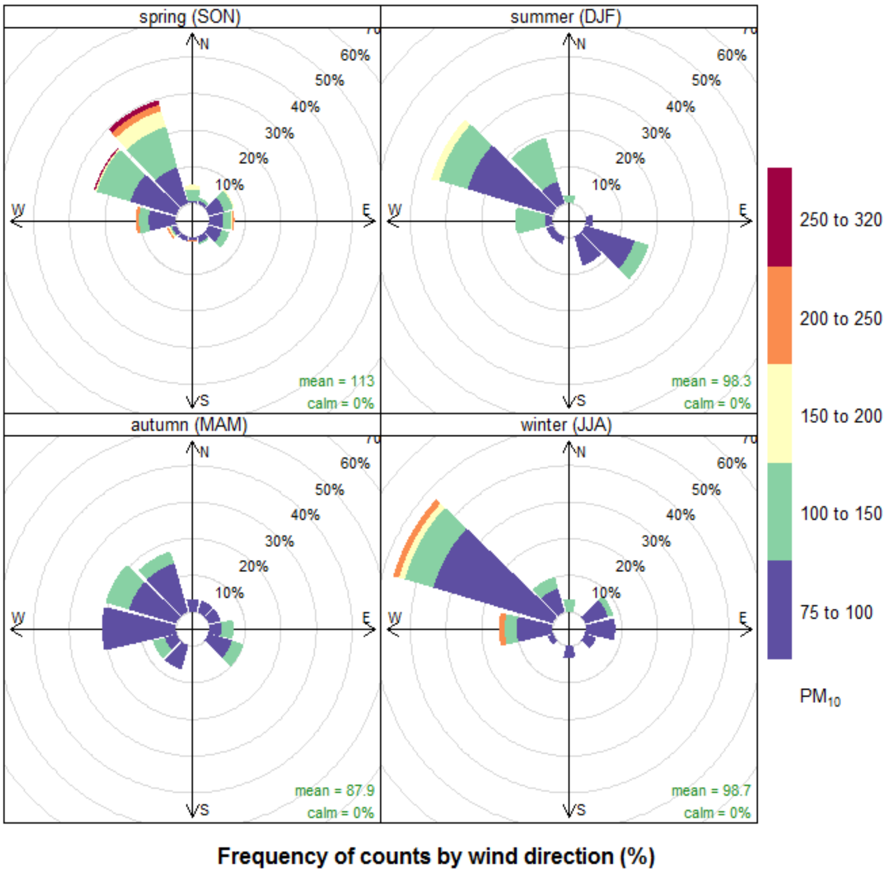


Figure 12: Camberwell – hourly average PM_{10} >75 µg/m^3 by season (2013)

Outcomes – how are dust emissions in the Upper Hunter being reduced?

Dust Stop

The Dust Stop program aims to reduce dust emissions by ensuring that best practice dust control options are implemented by coal mines throughout NSW. Under this program, all coal mines have compared their current operation with international best practice and were required to recommend how their dust controls can be improved.

The mines' reports confirm that wheel-generated dust is the primary source of PM_{10} on open cut mine sites, followed by the handling of overburden, and wind erosion of bare areas. To ensure that coal mines are implementing best practice dust controls, all open cut mines are now required to achieve 80% control of dust from their haul roads, and to cease or modify their overburden handling operations during adverse weather conditions. The mines are also required to investigate better ways of controlling dust from operations such as digging and dumping overburden.

All open cut coal mines have been required to monitor and report on these improved controls. The results of these monitoring programs reveal that coal mines across the state have implemented additional controls to ensure that they are achieving a haul road dust control of 80% or more. Across the state this will lead to a reduction in haul road dust emissions of 19,000 tonnes each year.

The reports also show that all open cut coal mines across NSW have implemented adverse weather response protocols across their sites. Whilst this means that every mine is responding to adverse weather in some form, individual mines are responding in different ways. The EPA intends to work more closely with mining industry to ensure greater consistency between mines in their response to adverse weather.

Dust Buster program

The EPA has implemented a Dust Buster program involving inspections of open-cut coal mines in the Hunter Valley in preparation for the onset of the windy conditions usually associated with spring.

The Dust Buster program specifically targets emissions associated with mine operations and complements the EPA's Dust Stop Pollution Reduction Program. Air quality readings in September and October show particulate matter generally peaks during these months. This is associated with the dry windy conditions often experienced in the Hunter Valley during spring.

The EPA is undertaking the Dust Buster inspection program, which will intensify during the windier months, to identify specific activities within coal mine operations that may be causing dust, and to require them to take appropriate action to address the issues identified.

The inspection program involves announced and unannounced inspections, including aerial surveillance of coal mines to check compliance with their licence conditions.

2.2 $PM_{2.5}$ monitoring data

$PM_{2.5}$ data are gathered at the Camberwell, Singleton Central and Muswellbrook Central monitoring stations. As can be seen from Figure 13, daily average values of $PM_{2.5}$ are elevated overall during the cooler winter months (light grey shaded area) compared to levels occurring throughout the warmer summer and autumn months; however, exceedences were experienced in late October during the NSW bushfire emergency.

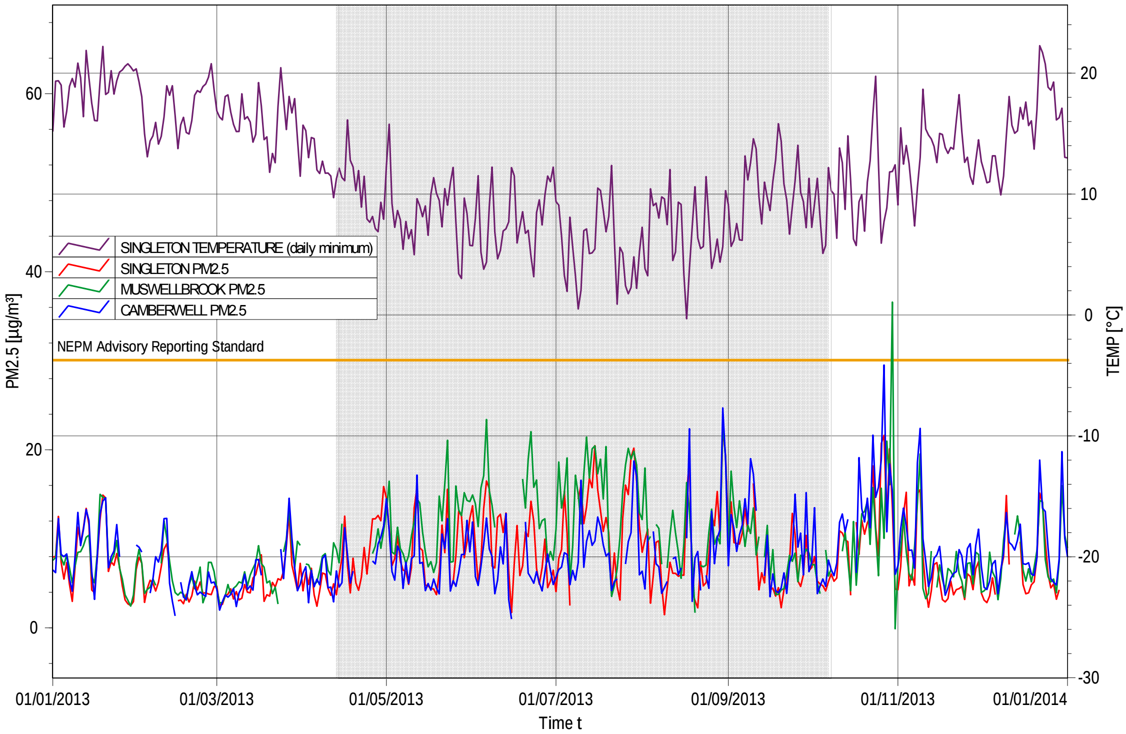


Figure 13: Singleton, Muswellbrook and Camberwell daily average $PM_{2.5}$ levels and Singleton minimum daily temperatures (2013)

Camberwell

Daily average $PM_{2.5}$ levels at Camberwell were less than the 25 µg/m^3 benchmark throughout the reporting period except for one day in October during the bushfire emergency (Figure 13 and Table 7). The annual average $PM_{2.5}$ level at Camberwell was 8.2 µg/m^3, which exceeds the benchmark of 8 µg/m^3.

Singleton Central

Daily and annual average $PM_{2.5}$ levels at Singleton Central were less than the 25 µg/m^3 and 8 µg/m^3 benchmarks throughout the reporting period (Figure 13).

Muswellbrook Central

Daily average $PM_{2.5}$ levels at Muswellbrook Central were less than the 25 μg/m^3 benchmark throughout the reporting period except for one day in October during the bushfire emergency (Figure 13 and Table 7). The annual average $PM_{2.5}$ level at Muswellbrook Central was 9.5 μg/m^3, which exceeds the benchmark of 8 μg/m^3.

Overall, the highest $PM_{2.5}$ concentrations at Muswellbrook occurred during the cooler months when residential wood fire use is high (Figure 13).

Table 7: Events above national $PM_{2.5}$ benchmarks (2013)

Station	Average	Standard (μg/m^3)	$PM_{2.5}$ (μg/m^3)	Date	Comments (including wind direction associated with elevated hourly values)
Camberwell	Daily	25	29.5	26/10/2013	Warm conditions, elevated levels during the day under light NW then E winds, bushfires
	Annual	8	8.2		
Muswellbrook central	Daily	25	36.6	29/10/2013	Warm conditions, elevated levels in the morning under very light variable winds, bushfires
	Annual	8	9.5		

Outcomes – How is air quality in the Upper Hunter being improved?

Particle characterisation study

The Upper Hunter Valley Particle Characterization Study, undertaken by the CSIRO and ANSTO for OEH and NSW Health during 2012 found that the highest contribution to annual $PM_{2.5}$ concentrations at Muswellbrook was found to be wood smoke (contributing around 30%) from domestic wood heaters. More information on this study is available at www.environment.nsw.gov.au/aqms/uhaqmnfpcs.htm.

Wood smoke reduction

As part of its ongoing work to reduce wood smoke, the EPA commenced the wood smoke reduction program (www.epa.nsw.gov.au/woodsmoke/wsrp2014.htm) in winter 2013. This comprehensive two-year program assists NSW local councils raise awareness about the health impacts of wood smoke, the benefits of correct wood heater operation and help their communities shift away from wood heaters to cleaner forms of heating. Muswellbrook, Singleton and Maitland councils received funds to implement a wood smoke reduction program through education, enforcement and provision of cash incentives for replacement of old heaters. The wood smoke reduction program has a budget of $930,000 for 2013–14 and $280,000 in 2014–15.

The EPA continued working with the Commonwealth and other jurisdictions towards developing national measures for wood heater management, as well as participating in a review of the Australian Standards for wood heaters.

2.3 Gaseous (NO_2 and SO_2) monitoring data

The gaseous pollutants nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) are measured at the Muswellbrook Central and Singleton Central monitoring sites. The hourly, daily and annual Air NEPM benchmarks were not exceeded at either monitoring site for NO_2 (Table 8 and Figure 14) or SO_2 (Table 9 and Figure 15).

Although SO_2 levels remained well below the relevant standards throughout the reporting period (see Appendix 5), Muswellbrook recorded a maximum hourly concentration of 14.8 pphm (Table 9), which is 74% of the benchmark. SO_2 levels at Muswellbrook are generally higher than those at Singleton (Figure 15).

In comparison to other regions within the NSW AQMN, the highest SO_2 levels in NSW occur in the Upper Hunter (Figure 16). Levels at Singleton were comparable to other regions (particularly the Lower Hunter), but levels at Muswellbrook are higher than elsewhere.

The higher levels of SO_2 (greater than 2 pphm) experienced by Muswellbrook were associated with winds from a south-easterly direction in summer and autumn (Figure 17 and Figure 18) and for Singleton were associated with winds from a north-westerly direction in spring, summer and winter (Figure 19 and Figure 20).

Table 8: Summary NO_2 at Singleton and Muswellbrook (2013)

Station	Annual average (pphm)	Hourly NO_2 values		Days above standards
		Maximum (pphm)	Date	
Muswellbrook	0.9	4.2	15/04/2013 19:00	0
Singleton	0.9	4.1	9/10/2013 23:00	0

Table 9: Summary SO_2 at Singleton and Muswellbrook (2013)

Station	Annual average (pphm)	Daily SO_2 average		Hourly SO_2 values		Days above standards
		Maximum (pphm)	Date	Maximum (pphm)	Date	
Muswellbrook	0.2	2.2	21/11/2013	14.8	25/01/2013 11:00	0
Singleton	0.1	0.8	26/04/2013	5.3	9/08/2013 13:00	0

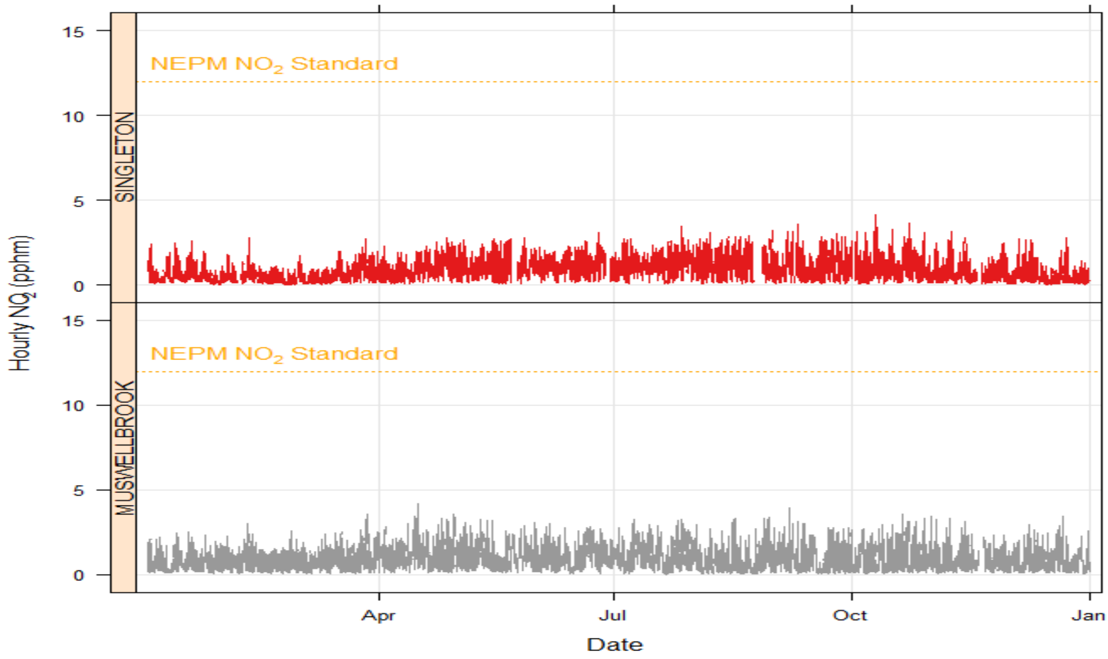


Figure 14: Muswellbrook and Singleton – hourly average NO_2 values (2013)

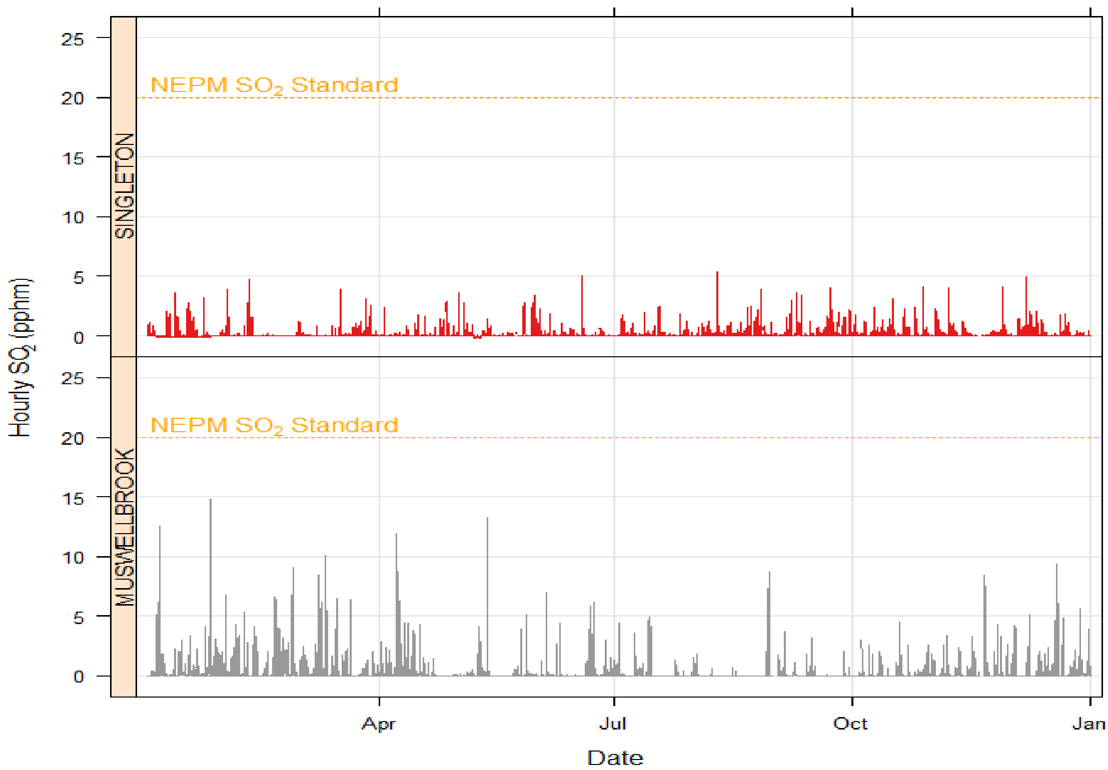


Figure 15: Muswellbrook and Singleton – hourly average SO_2 values (2013)

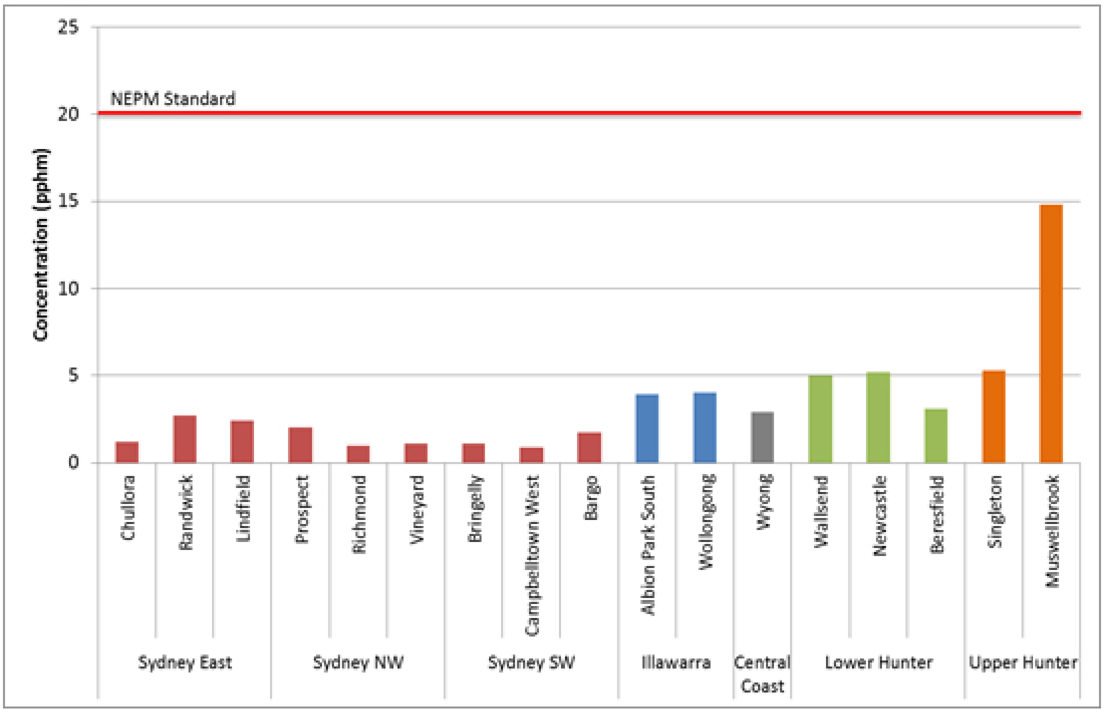
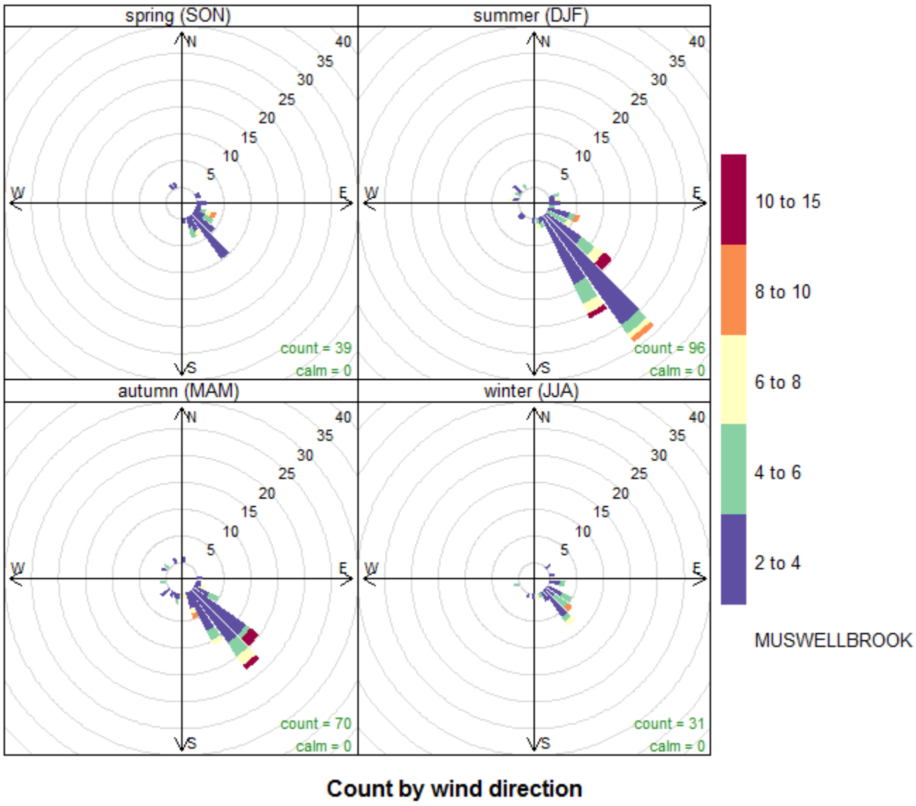


Figure 16: SO_2 annual hourly maximum concentration in NSW grouped by region (2013)



Count by wind direction

Figure 17: Muswellbrook – seasonal hourly average SO_2 values >2 pphm (2013)

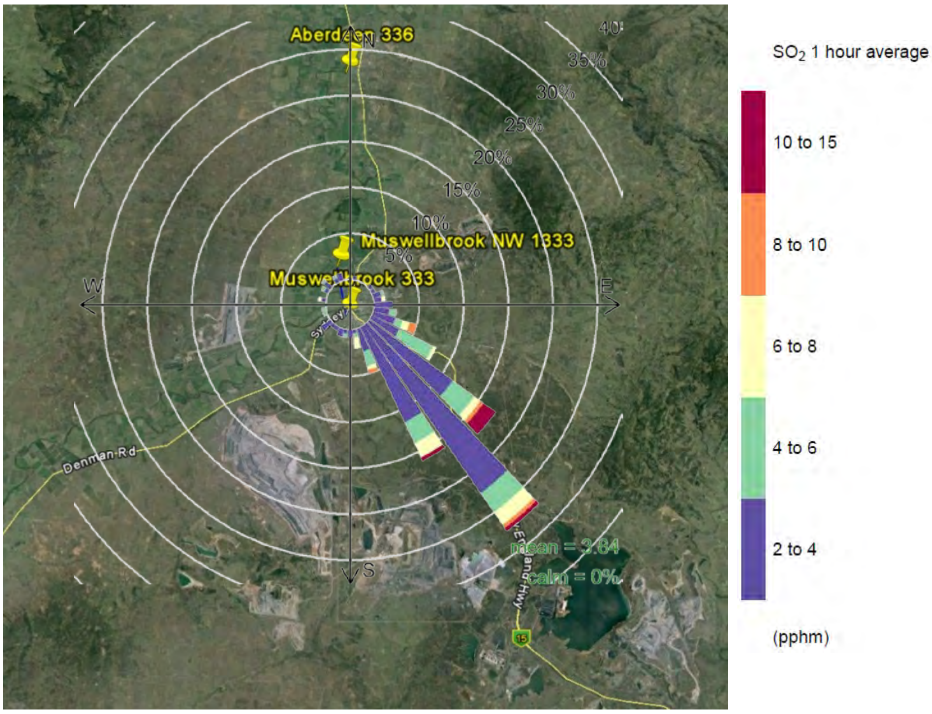


Figure 18: Muswellbrook – hourly average SO_2 values (>2 pphm) pollution rose for 2013

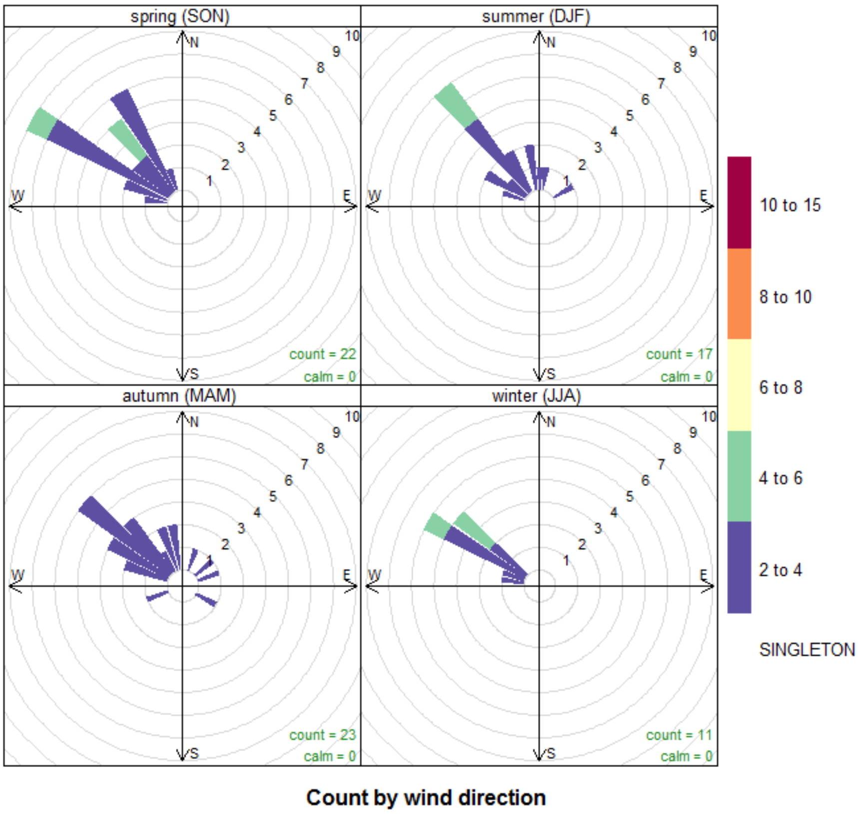


Figure 19: Singleton – seasonal hourly average SO_2 values >2 pphm (2013)

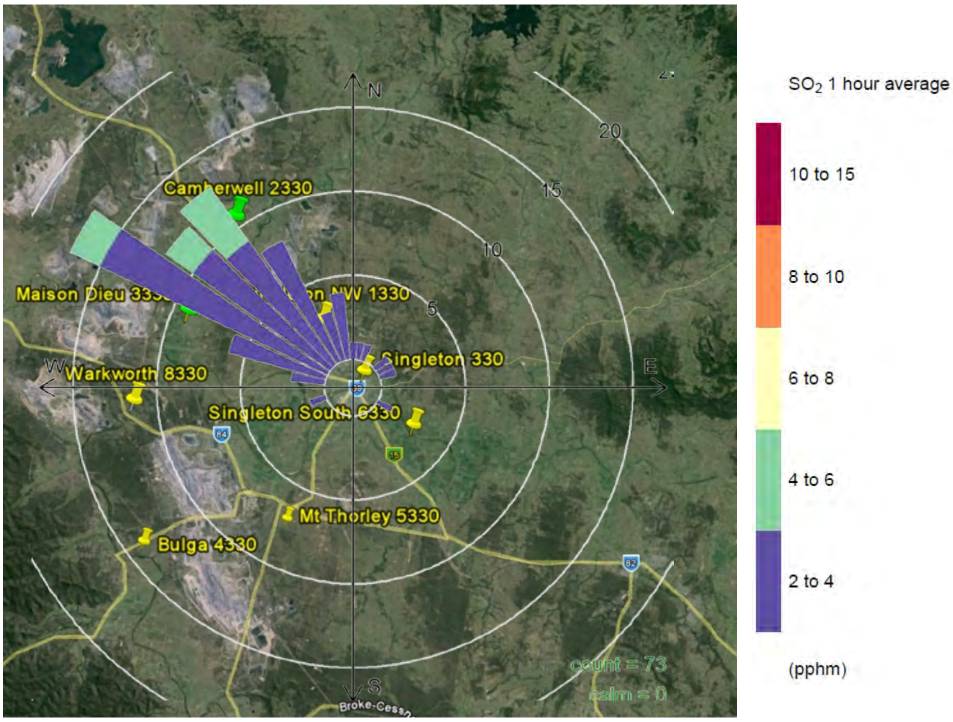


Figure 20: Singleton – hourly average SO_2 values (>2 pphm) pollution rose for 2013

CASE STUDY

SO_2 at Muswellbrook

Muswellbrook records higher maximum SO_2 levels compared to other sites within the NSW AQMN (Figure 16). During 2013, hourly averaged SO_2 levels above 10 pphm were recorded on five days within the reporting period. The highest of these was 14.8 pphm on 25 January 2013. The synoptic conditions on this day (Figure 21) show a high pressure system centred close to New Zealand. There is a ridge of high pressure extending from this system into the western Tasman Sea. This is accompanied by a cold front tracking towards the east, moving through south-east Australia. Similar synoptic patterns were experienced on all the days with SO_2 levels above 10 pphm at Muswellbrook.

Under this type of synoptic pattern, surface winds are typically found to be light and the atmosphere stable, which together can limit dispersion. Further, overnight conditions are generally expected to be clear and calm which can contribute to the development of a surface inversion in the valley. This is supported by the observations at Muswellbrook on this day (Figure 22), where winds were light throughout the day and the sigma theta[2] observations indicate a stable to very stable atmosphere in the early morning with the stable layer breaking down as the surface warmed up after sunrise[3].

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[2] Sigma theta measures the fluctuations in the horizontal wind direction.

[3] Stability classes were derived by using the sigma theta observations and applying the Pasquill-Gifford stability method followed by the Modified Sigma Theta method.

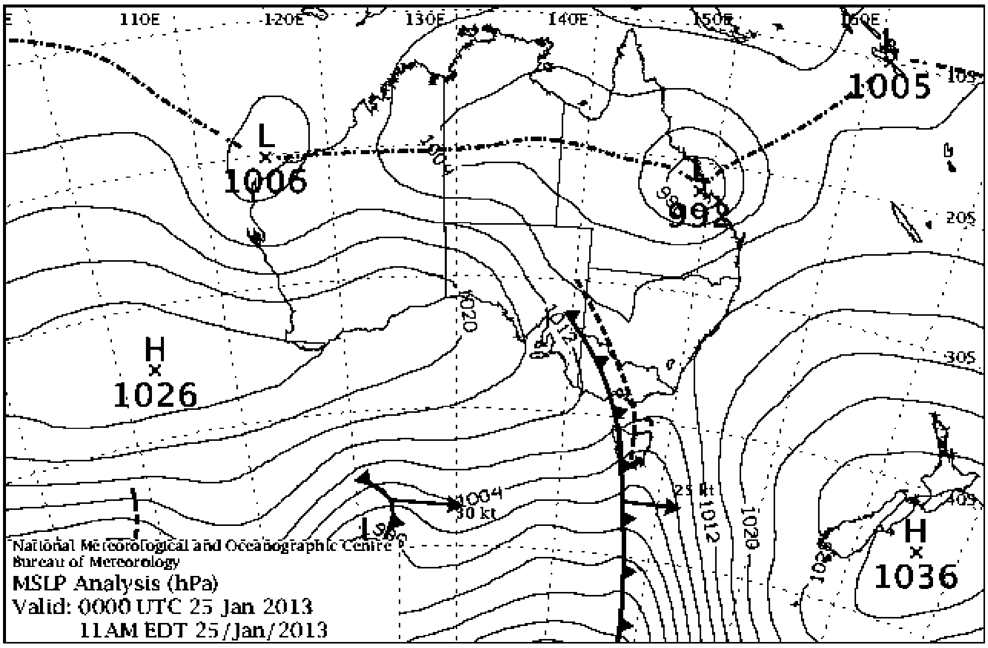


Figure 21: Bureau of Meteorology synoptic chart for 25 January 2013 00Z[4]

The Bureau of Meteorology upper air observational data from Williamtown[5] show an additional stable layer around 1000 m (Figure 23), which would further limit vertical dispersion.

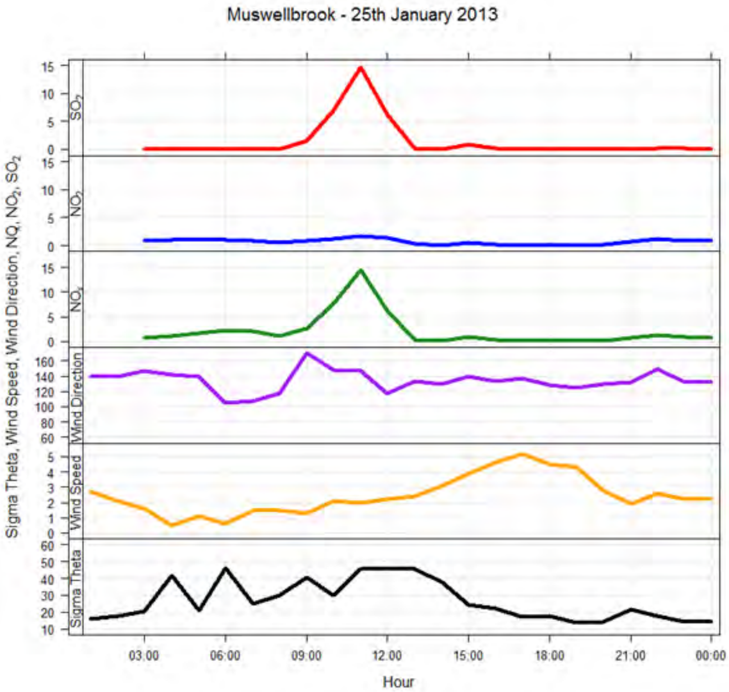


Figure 22: Time series plot of hourly SO_2 (pphm), NO_2 (pphm), NO_X (pphm), wind direction (°), wind speed (m/s) and sigma theta (°) at Muswellbrook on 25/01/2013

[4] Source: Bureau of Meteorology website, May 2014, www.bom.gov.au/australia/charts/archive/index.shtml

[5] Williamtown is approximately 100 km from Muswellbrook.

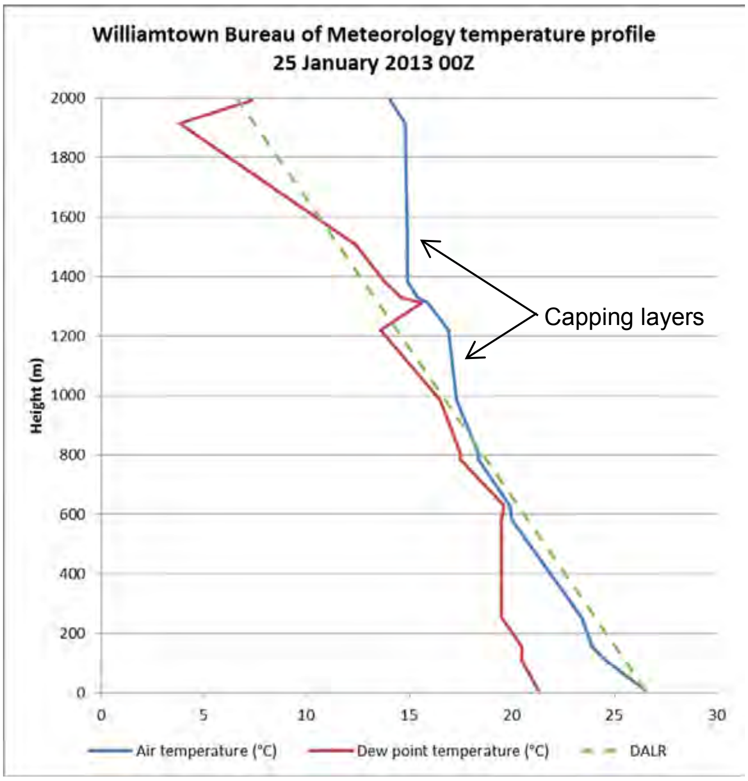


Figure 23: Upper air data from the BoM Williamtown site (ID 061078) at 25/01/2013 00Z[6]

Analysis of days with SO_2 levels greater than 10 pphm, shows spikes in NO_X coincident with the SO_2 peak. For example, coinciding increases in SO_2 and NO_X can be seen at 11 am on 25 January 2013 (Figure 22).

Hourly NO_X concentrations at Muswellbrook were compared to the SO_2 concentrations for the entire year (Figure 24); the scatter plot shows that when SO_2 concentrations increase, NO_X concentrations also increase; however, the reverse is not true as high NO_X concentrations occur at times of low level SO_2 concentrations.

[6] Upper air data obtained from the Bureau of Meteorology

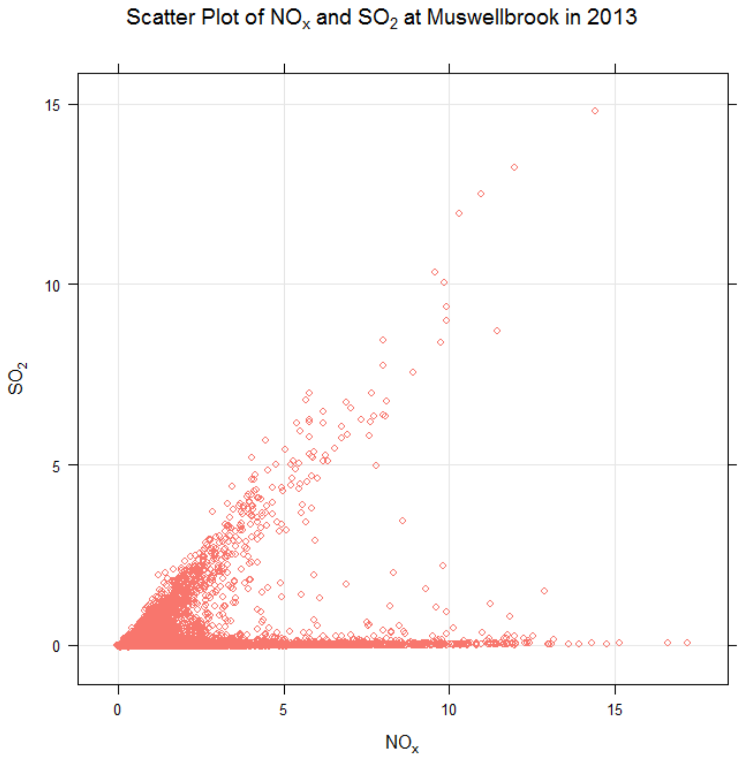


Figure 24: Scatter plot of hourly NO_X and SO_2 at Muswellbrook (2013)

At Singleton, SO_2 levels were found to be generally lower throughout the year than those at Muswellbrook (Table 9), with a maximum hourly concentration of 5.3 pphm compared to 14.8 pphm at Muswellbrook.

SO_2 and NO_X hourly concentrations at Singleton were plotted against each other for the whole year (Figure 25). This shows that, although the levels are seen to be much lower, a relationship is still apparent when SO_2 levels increase, as was seen at Muswellbrook.

Figure 20 shows that hourly average SO_2 values >2 pphm occur at Singleton under north-westerly winds, so are not expected to coincide with elevated levels at Muswellbrook (which occur under the opposite wind direction). This can be seen in Figure 26, which shows that on 25 January 2013 (when Muswellbrook recorded an hourly SO_2 maximum of 14.8 pphm), Singleton recorded no SO_2 and very low NO_X levels.

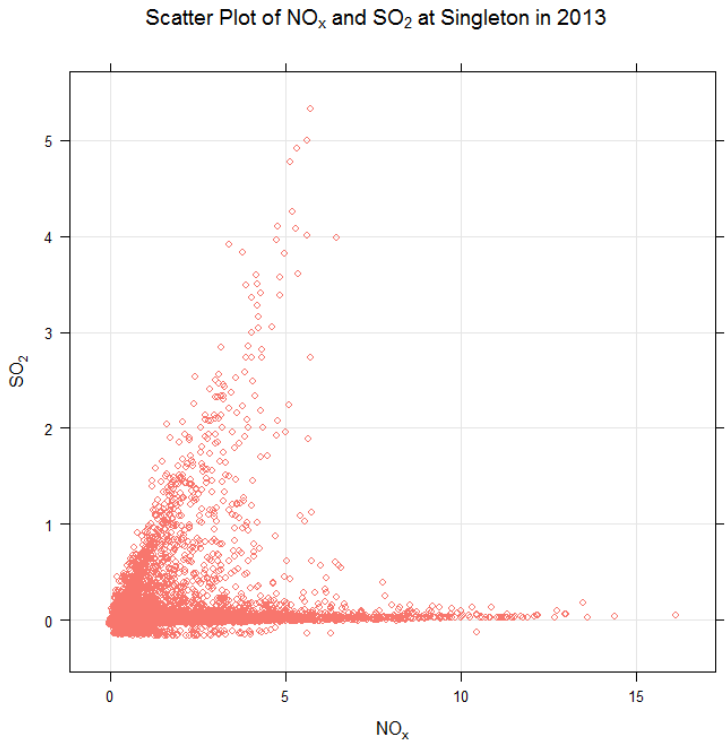


Figure 25: Scatter plot of hourly NO_X and SO_2 at Singleton (2013)

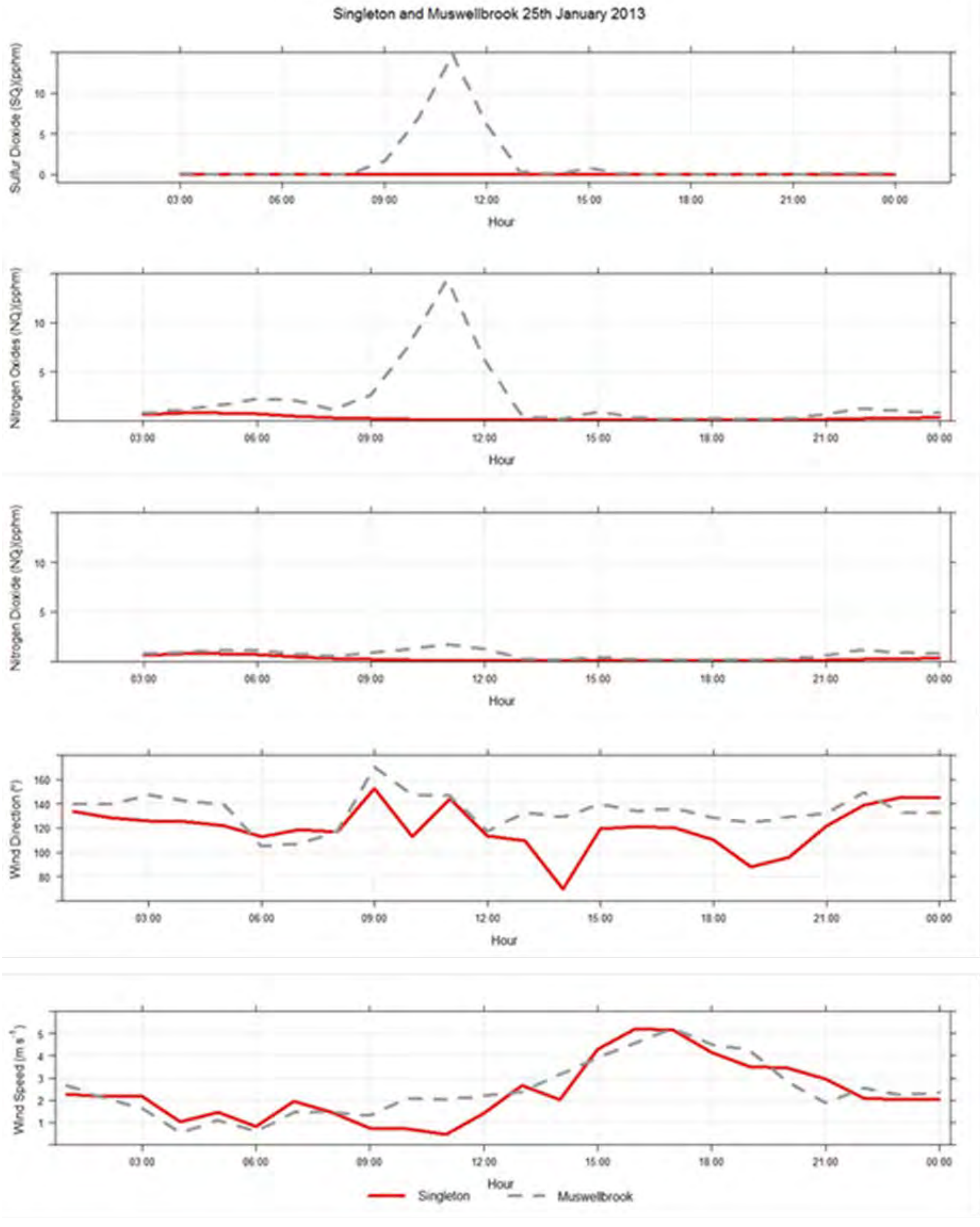


Figure 26: Time series plot of hourly SO_2 (pphm), NO_2 (pphm), NO_X (pphm), wind direction (º) and wind speed (m/s) at Singleton (and Muswellbrook in grey) on 25/01/2013

Discussion

There were five days during 2013 when hourly SO_2 levels greater than 10 pphm were recorded at Muswellbrook. These levels are higher than those found in other regions in the NSW AQMN. Observational meteorological data have been presented for 25 January 2013, when an hourly SO_2 level of 14.8 pphm (74% of the national hourly standard) was recorded at Muswellbrook.

The main source of SO_2 within the region is from electricity generation at the power stations[7]. The meteorology data presented here, such as the vertical profiles and surface meteorological data, are the first step in understanding the conditions that lead to elevated levels of SO_2 occurring periodically at Muswellbrook. With limited vertical dispersion and light winds, plumes can be transported aloft some distance from their sources and can then be mixed down to the surface once the stable atmosphere is broken down during the morning with warming from the sun.

NSW OEH will conduct dispersion modelling in the Upper Hunter to gain a better understanding of the atmospheric processes involved with the transport of SO_2 within the region.

[7] Sourced from the EPA 2008 Calendar Year Air Emissions Inventory for the Greater Metropolitan Region in NSW; www.epa.nsw.gov.au/air/airinventory2008.htm.

2.4 Meteorological conditions

The Bureau of Meteorology (BoM) Annual Climate Summaries for NSW and the Upper Hunter for 2013 and 2012 are included in Table 10 (for comparative purposes). This summary is depicted in the interannual rainfall difference and rainfall and temperature deciles maps[8] (Appendix 7 – Figure 29 to Figure 35).

Table 10: Rainfall and temperatures in NSW and the Upper Hunter region (2012–2013)

Year	Met conditions	NSW[(1)]	Upper Hunter[(2)]
2013	ENSO (El Niño–Southern Oscillation)	• 2013 was a neutral year for the ENSO, with neither El Niño nor La Niña influencing Australian temperatures and rainfall.	
	Rainfall	• NSW recorded a statewide average rainfall of 463.4 mm during 2013, which is 16% below the historical average of 552.7 mm and the driest year since 2006. • Rainfall was above average along the coast, with several heavy rain events, but below average in inland NSW and across the Murray Darling Basin.	• Average to above average rainfall • Approximately 100–200 mm higher rainfall in 2013 compared to 2012
	Temperature	• 2013 was the warmest year on record for NSW maximum temperatures, and the third-warmest for mean temperatures. • The state recorded the warmest January and September maximum temperatures on record plus a record warm July to October period.	• Above average maximum temperatures • Close to average minimum temperatures
	Bushfires	• Widespread bushfires impacted the state during January. • Early season bushfires occurred on the coastal strip in September. • Bushfires affected much of the coastal strip during October, the worst fires in NSW (in terms of losses) since the 1960s.	

[8] Maps obtained from the Bureau of Meteorology website (www.bom.gov.au/climate/maps) accessed in April 2014.

Table 10 continued

Year	Met conditions	NSW[1]	Upper Hunter[2]
2012	ENSO (El Niño–Southern Oscillation)	• One of the most significant La Niña events in Australia's recorded meteorological history[3]	
	Rainfall	• Close to average rainfall overall • The 2011–12 La Niña event was the major influence on NSW rainfall at the start of the year, with most of the state experiencing rainfall in the wettest 10% of years • In comparison, the combination of a strong high pressure ridge and a positive Indian Ocean Dipole event in late winter resulted in generally dry conditions for the rest of the year. The statewide average rainfall for April to December was just 246.4 mm, the driest such period since 2006.	• Average to below average rainfall
	Temperature	• Warm days, coldest nights since 1994 • The statewide average temperature for NSW during 2012 was 0.16 °C above the 1961–90 average, with close to average temperatures across the state.	• Close to average maximum temperatures • Below average minimum temperatures
	Floods	• Flooding was widespread and severe during the first part of the year. More than 75 percent of the state was affected by flood warnings in early March, with Natural Disasters declared in 63 LGAs by the end of March.	

(1) The NSW summaries were obtained from the Bureau of Meteorology Annual Climate Summary for NSW – 2013 (www.bom.gov.au/climate/current/annual/nsw/summary.shtml) and 2012 (www.bom.gov.au/climate/current/annual/nsw/archive/2012.summary.shtml), accessed June 2014.
(2) The Upper Hunter summaries are interpreted from the BoM deciles maps (Appendix 7).
(3) Bureau of Meteorology website (www.bom.gov.au/climate/enso/history/ln-2010-12) accessed in June 2014.

Although the Hunter Valley region recorded higher rainfall in 2013 compared to 2012, a key difference between the two years is the impact of widespread bushfires in 2013, compared to widespread floods in 2012. Bushfires were also present in the region during November, as noted within the Rural Fire Service database.

Wind patterns vary from site to site within the Upper Hunter as a result of local topographical features; however, overall they are typically found to flow along the valley at most sites. Appendix 8 includes the annual wind roses for each site, showing that predominant winds are from the north-west and south-east sectors throughout the year.

2.5 What do the air quality results tell us?

During 2013, of the two major population centres, the Air NEPM goal for 24-hour PM_{10} was met at Muswellbrook Central (with three days exceeding the national standard of 50 ug/m^3) but was not met at Singleton Central (with 12 days exceeding the national standard). These exceedence days occurred during the warmer months and were most often associated with light variable winds or down valley (north-westerly) winds. Significant bushfire events during January and September–November also contributed to these high levels.

For $PM_{2.5}$, Singleton Central met the relevant national advisory reporting standards, while at Muswellbrook Central there was one day above the national daily standard and the annual standard of 8 µg/m^3 was exceeded. At Muswellbrook, smoke from residential wood fires affects $PM_{2.5}$ levels during the cooler months and can account for 30% of total annual $PM_{2.5}$ in the town.

The SO_2 case study at Muswellbrook identified that the highest levels of SO_2 observed in the NSW AQMN are in the Upper Hunter. Detailed dispersion modelling will be undertaken by NSW OEH to gain a better understanding of the atmospheric processes involved with the transport of SO_2 within the region.

Throughout the rest of the Upper Hunter, particle levels and the number of days exceeding benchmarks (Table 11) were significantly influenced by major bushfires during January and September–November.

Appendix 1: Days when levels were above the benchmarks

The monthly breakdown of days when levels above the PM_{10}, $PM_{2.5}$, NO_2 and SO_2 benchmarks were recorded during 2013 are found in Table 11.

Table 12 includes the days over the PM_{10} benchmark, with the maximum 24-hour average PM_{10} level and the list of stations over the PM_{10} benchmark on each of these days, providing an indication of spatial extent.

Table 11: Number of days exceeding PM_{10}, $PM_{2.5}$, NO_2 and SO_2 benchmarks (2013)

Parameter	Purpose	Station	Month	No. of days exceeding benchmark at each site
PM_{10}	Population centre	Muswellbrook Central	Sep	1
			Oct	1
			Nov	1
		Singleton Central	Jan	3
			Sep	2
			Oct	4
			Nov	2
			Dec	1
	Smaller community	Bulga	Jan	2
			Apr	1
			Oct	2
			Nov	1
			Dec	1
		Camberwell	Jan	4
			Apr	2
			Aug	5
			Sep	8
			Oct	11
			Nov	3
			Dec	3
		Jerrys Plains	Apr	1
			Oct	4
			Nov	1

Table 11 continues overleaf.

Table 11 continued

Parameter	Purpose	Station	Month	No. of days exceeding benchmark at each site
PM_{10} continued	Smaller community	Maison Dieu	Jan	4
			Apr	1
			Aug	2
			Sep	5
			Oct	11
			Nov	2
			Dec	3
		Warkworth	Apr	1
			Oct	4
			Nov	2
			Dec	1
		Wybong	Oct	2
	Diagnostic	Mount Thorley	Jan	2
			Apr	3
			Aug	2
			Sep	4
			Oct	12
			Nov	1
			Dec	2
		Muswellbrook NW	Nov	1
		Singleton NW	Jan	4
			Apr	2
			Aug	2
			Sep	6
			Oct	10
			Nov	2
			Dec	2
	Background	Singleton South	Oct	4
			Nov	1
$PM_{2.5}$	Population centre	Muswellbrook	Oct	1
	Smaller community	Camberwell	Oct	1
NO_2/SO_2	Population centre	Muswellbrook		Nil
		Singleton		Nil

Note that some of the days exceeding the benchmark are common to multiple sites. During 2013, there were 46 distinct days above the PM_{10} benchmark and two distinct days above the $PM_{2.5}$ benchmark.

Table 12: PM_{10} exceedence days (2013) for all station types (red = larger population centre; blue = smaller community; green = diagnostic; black = background)

Date	Max daily PM_{10} (µg/m^3)	No. sites above benchmark	Station	Daily PM_{10} (µg/m^3)
08/01/2013	68.6	4	Singleton	54.5
			Camberwell	55.1
			Maison Dieu	52.2
			Singleton NW	68.6
09/01/2013	58.8	5	Singleton	58.6
			Bulga	55.0
			Camberwell	58.0
			Maison Dieu	58.8
			Singleton NW	54.2
12/01/2013	56.6	3	Camberwell	51.0
			Mount Thorley	56.6
			Singleton NW	50.5
17/01/2013	53.0	2	Bulga	53.0
			Maison Dieu	50.8
18/01/2013	68.5	5	Singleton	51.2
			Camberwell	53.3
			Maison Dieu	68.5
			Mount Thorley	53.5
			Singleton NW	60.0
15/04/2013	58.2	2	Mount Thorley	58.2
			Singleton NW	52.9
28/04/2013	76.1	2	Camberwell	52.9
			Mount Thorley	76.1
29/04/2013	88.4	7	Bulga	88.4
			Camberwell	55.5
			Jerrys Plains	58.6
			Maison Dieu	55.1
			Mount Thorley	67.4
			Singleton NW	58.9
			Warkworth	65.0
14/08/2013	50.1	1	Camberwell	50.1
17/08/2013	59.7	4	Camberwell	59.6
			Maison Dieu	52.6
			Mount Thorley	59.7
			Singleton NW	57.7
19/08/2013	56.7	1	Camberwell	56.7

Table 12 continued

Date	Max daily PM_{10} (µg/m^3)	No. sites above benchmark	Station	Daily PM_{10} (µg/m^3)
23/08/2013	53.9	1	Camberwell	53.9
30/08/2013	61.9	3	Camberwell	61.9
			Maison Dieu	53.4
			Singleton NW	50.2
31/08/2013	59.3	1	Mount Thorley	59.3
01/09/2013	52.2	1	Muswellbrook	52.2
05/09/2013	57.6	2	Camberwell	54.4
			Singleton NW	57.6
06/09/2013	55.2	4	Singleton	53.3
			Camberwell	50.6
			Maison Dieu	53.0
			Singleton NW	55.2
07/09/2013	63.7	4	Camberwell	63.7
			Maison Dieu	52.3
			Mount Thorley	62.7
			Singleton NW	58.9
10/09/2013	73.1	5	Singleton	59.5
			Camberwell	71.7
			Maison Dieu	69.0
			Mount Thorley	67.8
			Singleton NW	73.1
23/09/2013	51.2	1	Camberwell	51.2
24/09/2013	82.9	4	Camberwell	82.9
			Maison Dieu	54.3
			Mount Thorley	72.9
			Singleton NW	69.1
26/09/2013	77.6	4	Camberwell	70.0
			Maison Dieu	62.9
			Mount Thorley	77.6
			Singleton NW	73.2
28/09/2013	62.1	1	Camberwell	62.1
01/10/2013	91.7	4	Camberwell	84.0
			Maison Dieu	75.8
			Mount Thorley	71.8
			Singleton NW	91.7

Table 12 continued

Date	Max daily PM_{10} (µg/m^3)	No. sites above benchmark	Station	Daily PM_{10} (µg/m^3)
06/10/2013	58.3	2	Camberwell	58.3
			Maison Dieu	51.5
10/10/2013	74.9	6	Singleton	58.4
			Camberwell	74.9
			Maison Dieu	62.5
			Mount Thorley	50.2
			Singleton NW	62.4
			Singleton South	55.4
13/10/2013	99.3	7	Singleton	57.9
			Camberwell	99.3
			Maison Dieu	80.9
			Warkworth	57.7
			Mount Thorley	62.9
			Singleton NW	64.1
			Singleton South	50.5
15/10/2013	56.8	2	Camberwell	56.8
			Singleton NW	52.6
16/10/2013	64.2	3	Camberwell	62.3
			Maison Dieu	64.2
			Mount Thorley	62.4
17/10/2013	104.8	8	Singleton	62.7
			Camberwell	104.8
			Jerrys Plains	56.1
			Maison Dieu	79.8
			Warkworth	50.5
			Mount Thorley	88.3
			Singleton NW	76.0
			Singleton South	60.3
18/10/2013	83.0	1	Wybong	83.0
19/10/2013	75.1	1	Wybong	75.1
21/10/2013	54.5	5	Camberwell	51.1
			Jerrys Plains	52.2
			Maison Dieu	54.5
			Mount Thorley	50.6
			Singleton NW	53.4

Table 12 continued

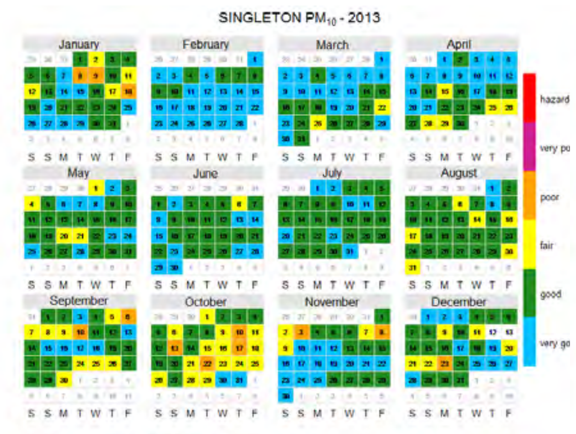
Date	Max daily PM_{10} (µg/m^3)	No. sites above benchmark	Station	Daily PM_{10} (µg/m^3)
22/10/2013	85.2	9	Singleton	57.3
			Bulga	56.3
			Camberwell	85.2
			Jerrys Plains	59.4
			Maison Dieu	84.2
			Warkworth	65.4
			Mount Thorley	75.3
			Singleton NW	67.8
			Singleton South	53.0
23/10/2013	65.3	3	Camberwell	65.3
			Maison Dieu	52.6
			Mount Thorley	59.1
24/10/2013	59.8	1	Mount Thorley	59.8
25/10/2013	66.4	3	Maison Dieu	56.2
			Mount Thorley	66.4
			Singleton NW	64.1
26/10/2013	65.6	6	Camberwell	57.5
			Jerrys Plains	63.3
			Maison Dieu	65.6
			Mount Thorley	50.1
			Singleton NW	56.1
			Warkworth	52.5
28/10/2013	53.3	1	Bulga	53.3
29/10/2013	57.1	3	Muswellbrook	55.6
			Mount Thorley	57.1
			Singleton NW	52.3
03/11/2013	69.7	7	Singleton	53.5
			Bulga	64.3
			Camberwell	66.3
			Maison Dieu	69.7
			Warkworth	57.9
			Singleton NW	61.5
			Singleton South	54.0

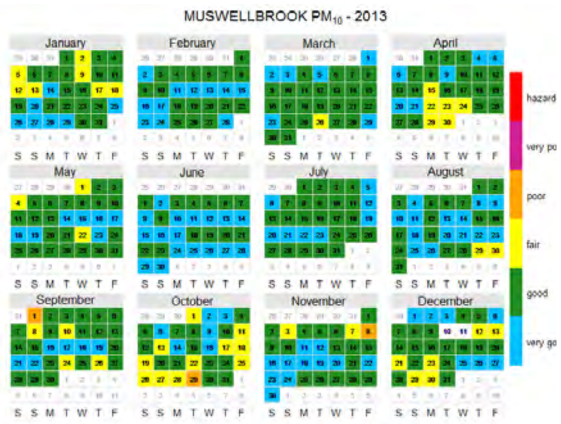
Table 12 continued

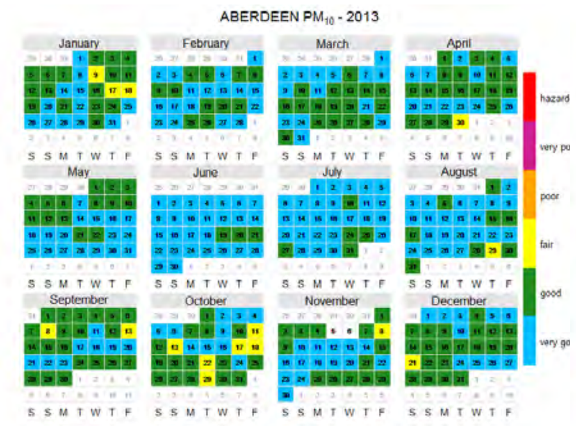
Date	Max daily PM_{10} (µg/m^3)	No. sites above benchmark	Station	Daily PM_{10} (µg/m^3)
08/11/2013	94.7	9	Muswellbrook	54.3
			Singleton	52.2
			Camberwell	94.7
			Jerrys Plains	58.7
			Maison Dieu	79.9
			Warkworth	54.1
			Mount Thorley	78.3
			Muswellbrook NW	52.4
			Singleton NW	85.0
09/11/2013	53.0	1	Camberwell	53.0
09/12/2013	58.5	4	Camberwell	58.5
			Maison Dieu	55.4
			Mount Thorley	50.5
			Singleton NW	51.7
21/12/2013	62.1	3	Bulga	50.5
			Camberwell	50.4
			Maison Dieu	62.1
23/12/2013	66.5	6	Singleton	51.4
			Camberwell	62.5
			Maison Dieu	66.5
			Warkworth	51.9
			Mount Thorley	53.4
			Singleton NW	61.5

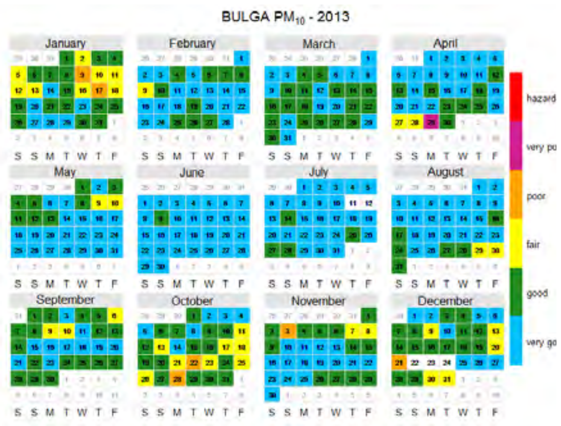
Appendix 2: Daily average PM_{10} data

The following calendar plots show daily average PM_{10} levels categorised against a benchmark of 50 µg/m^3. Days where levels are higher than the benchmark are coloured orange, maroon or red. The categories are those used in the OEH Regional Air Quality Index webpages (www.environment.nsw.gov.au/aqms/aqi.htm).

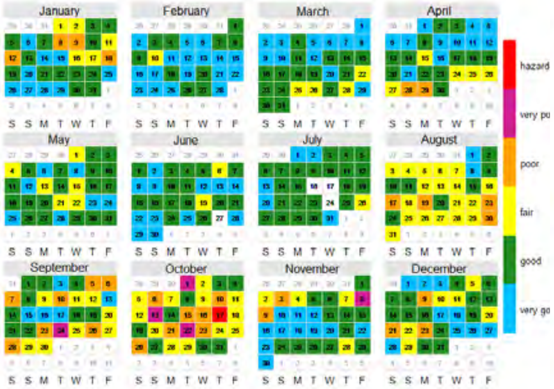




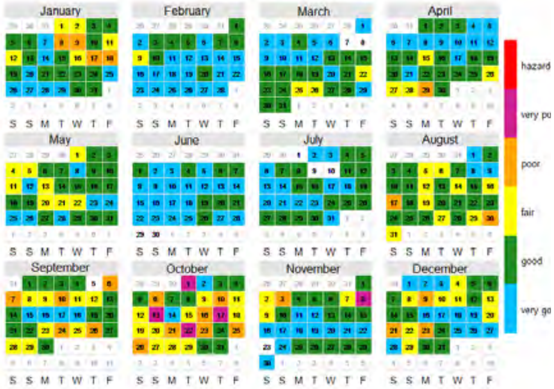




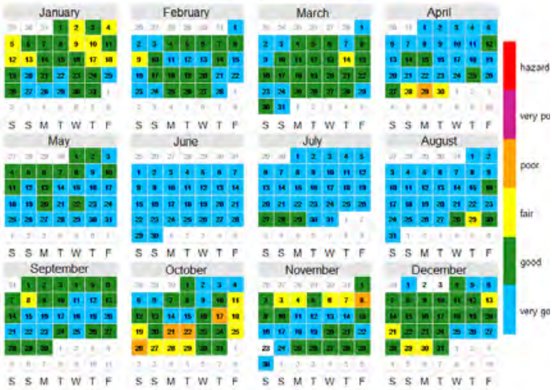
CAMBERWELL PM_{10} - 2013



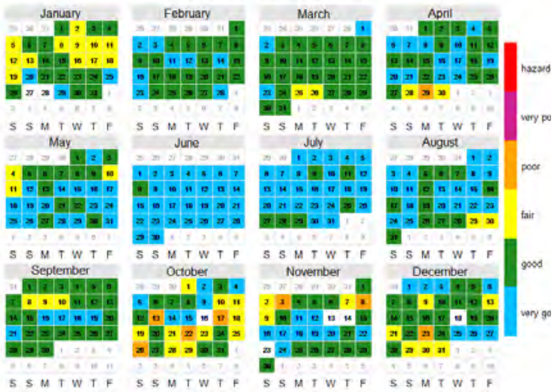
MAISON DIEU PM_{10} - 2013



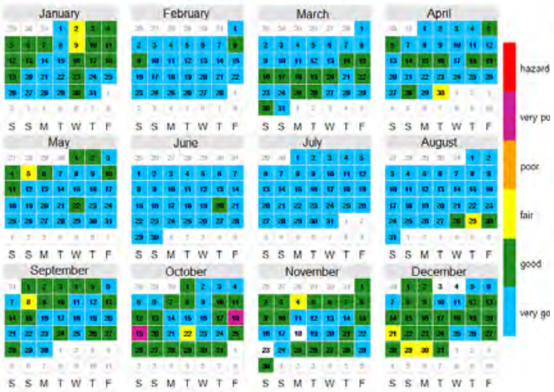
JERRYS PLAINS PM_{10} - 2013



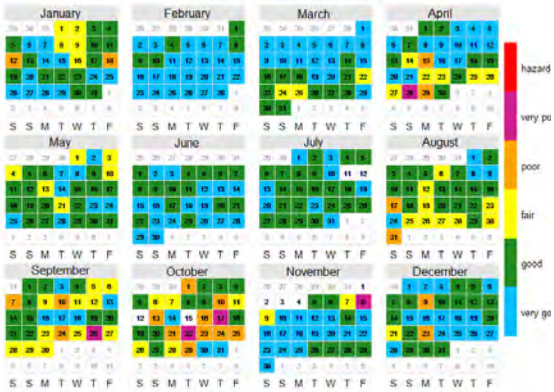
WARKWORTH PM_{10} - 2013

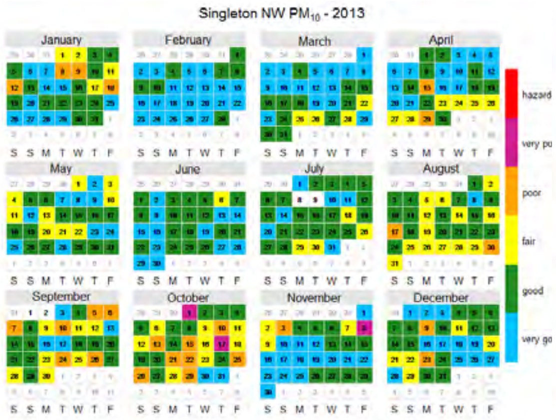


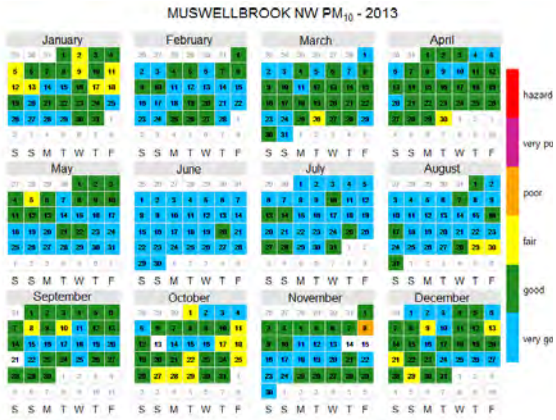
WYBONG PM_{10} - 2013



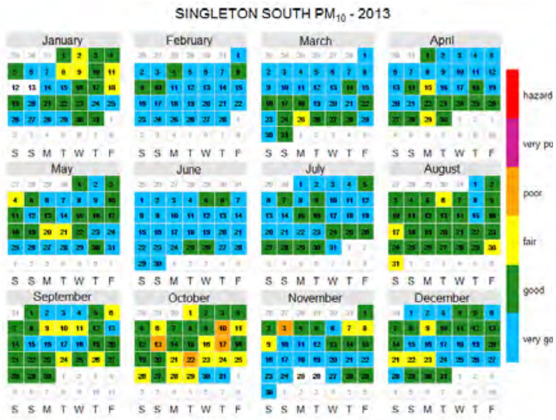
MOUNT THORLEY PM_{10} - 2013




Singleton NW PM_{10} - 2013
January
February
March
April
May
June
July
August
September
October
November
December
hazard
very po
poor
fair
good
very go

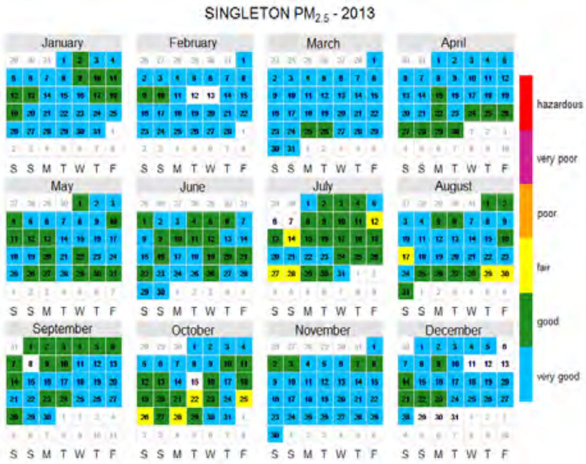

MUSWELLBROOK NW PM_{10} - 2013
January
February
March
April
May
June
July
August
September
October
November
December
hazard
very po
poor
fair
good
very go

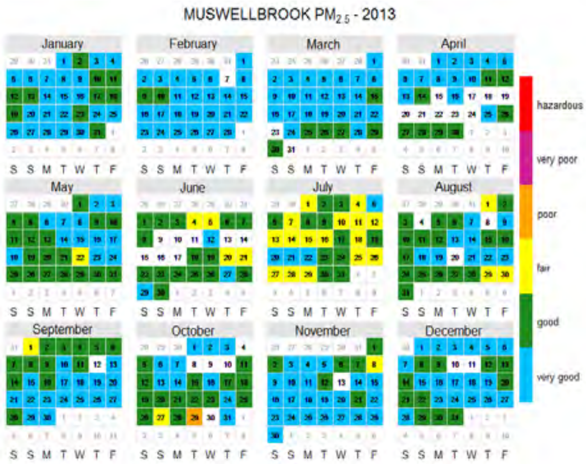

MERRIWA PM_{10} - 2013
January
February
March
April
May
June
July
August
September
October
November
December
hazard
very po
poor
fair
good
very go

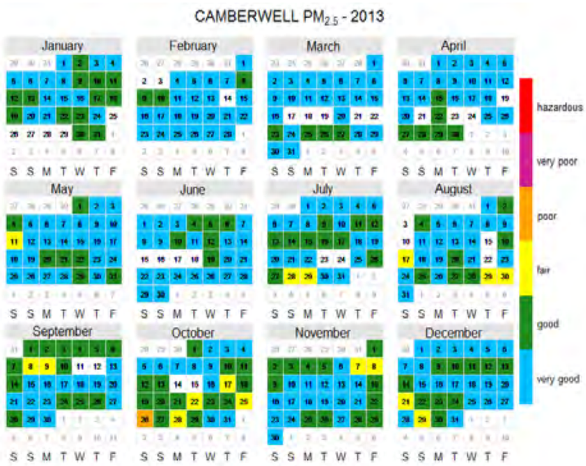

SINGLETON SOUTH PM_{10} - 2013
January
February
March
April
May
June
July
August
September
October
November
December
hazard
very po
poor
fair
good
very go

Appendix 3: Daily average $PM_{2.5}$ data

The following calendar plots show daily average $PM_{2.5}$ levels categorised against a benchmark of 25 µg/m^3. Days where levels are higher than the benchmark are coloured orange, maroon or red. The categories are those used in the OEH Regional Air Quality Index webpages (www.environment.nsw.gov.au/aqms/aqi.htm).

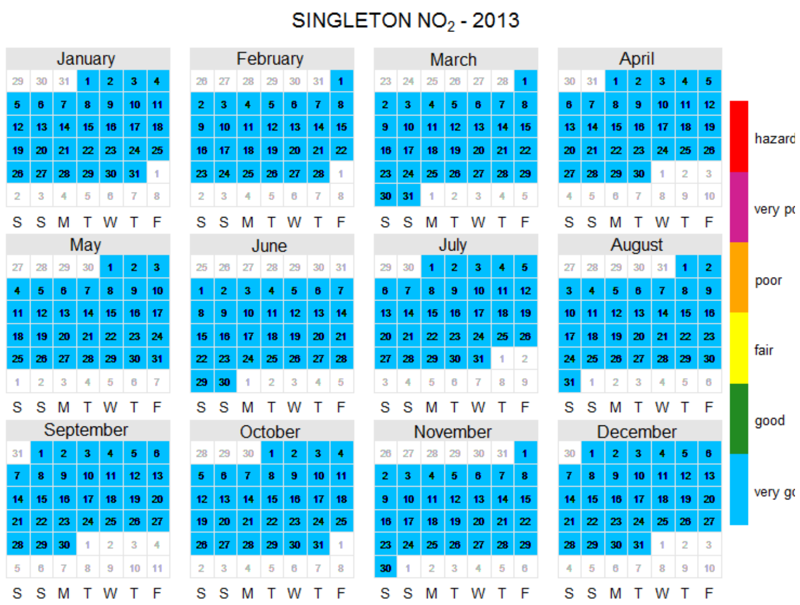


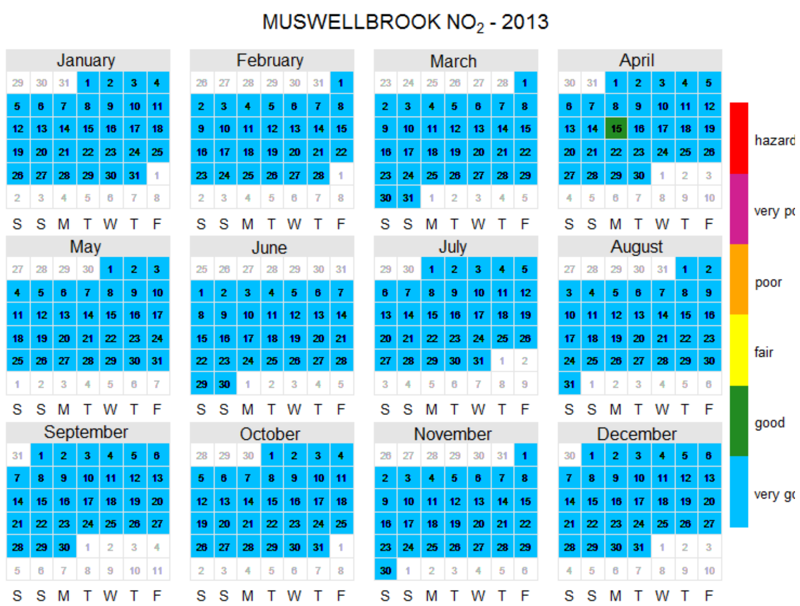




Appendix 4: Daily maximum NO_2 data

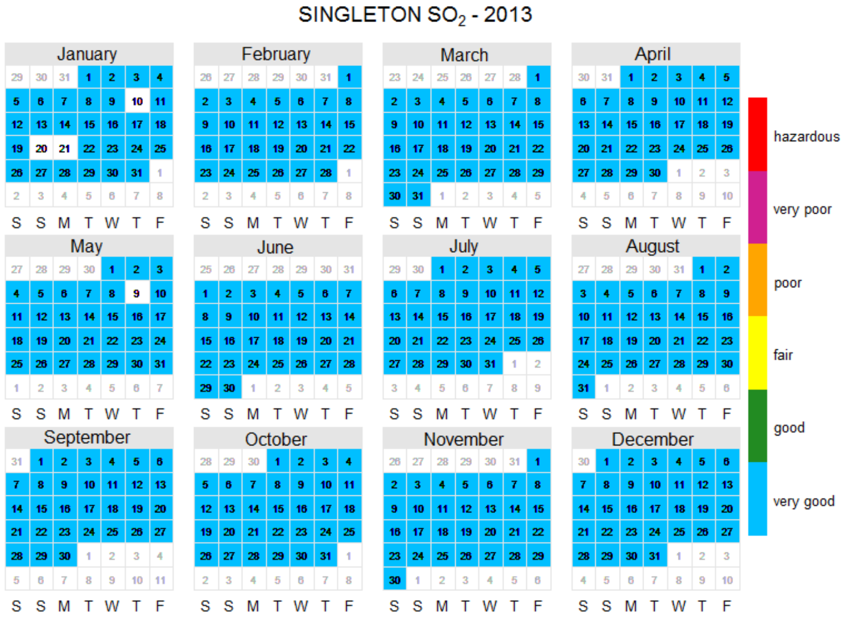
The following calendar plots show daily maximum 1-hour NO_2 levels categorised against a benchmark of 12 parts per hundred million (pphm). Days where levels are higher than the benchmark are coloured orange, maroon or red. The categories are those used in the OEH Regional Air Quality Index webpages (www.environment.nsw.gov.au/aqms/aqi.htm).

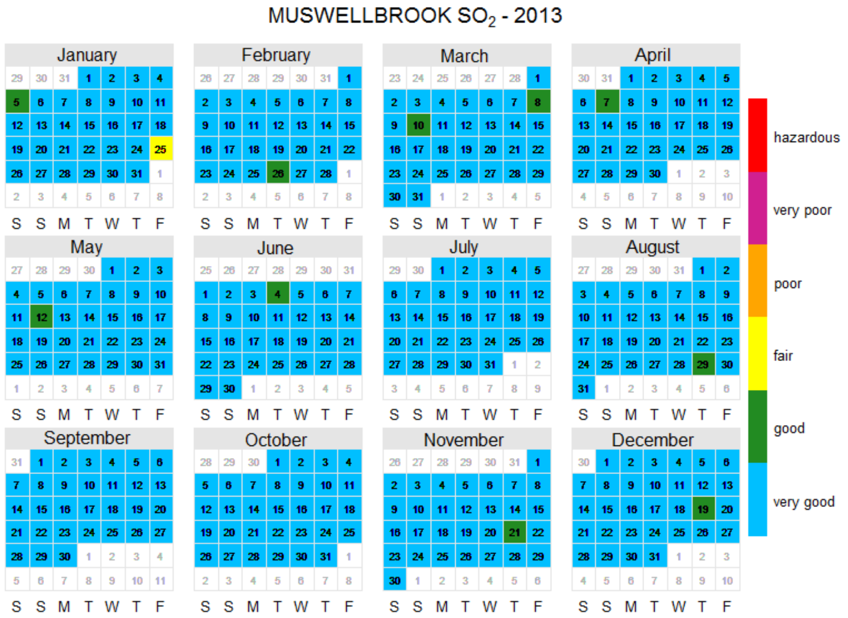




Appendix 5: Daily maximum SO_2 data

The following calendar plots show daily maximum 1-hour SO_2 levels categorised against a benchmark of 20 parts per hundred million (pphm). Days where levels are higher than the benchmark are coloured orange, maroon or red. The categories are those used in the OEH Regional Air Quality Index webpages (www.environment.nsw.gov.au/aqms/aqi.htm).





Appendix 6: How are particles measured in the UHAQMN?

Two methods can be used to collect air quality data:

- **Reference methods:** involve batch collection of fine particles on filter paper over 24 hours. Samples are collected and then transported to special laboratory facilities for weighing and reporting of results. This process can take 2–3 weeks.
- **Continuous methodologies:** because of the time lag associated with reference methods, OEH chose recognised techniques to provide the continuous data required for the web-based community reporting and alert systems which it operates.

Two different types of continuous monitoring instruments are used throughout the UHAQMN, one measuring PM_{10} and one $PM_{2.5}$. Both are recognised as equivalent methods to the relevant reference method by the US Environmental Protection Agency and are designated as Federal Equivalent Methods (FEM).

Measurement of PM_{10}

The Tapered Element Oscillating Microbalance (TEOM) instrument was chosen for the continuous measurement of PM_{10} (Figure 27). A TEOM PM_{10} instrument is located in each of the 14 monitoring stations making up the UHAQMN.

These instruments, fitted with a size-selective PM_{10} inlet, draw a constant volume of ambient air through a filter which is mounted on a vibrating hollow glass tube (the tapered element). Particles are collected on the filter, which then increases in weight. This additional weight changes the frequency at which the tapered element vibrates (or oscillates) from one side to the other. The mass of the particles is determined by the change in oscillation frequency. The mass is divided by the volume of air sampled by the instrument over the same time period to produce the mass/unit volume (micrograms/cubic metre: $\mu g/m^3$).

Because the particles can include water (via rain or humidity) as part of their mass, the sensor unit is heated to 50°C to remove water from the particles collected on the filter. The TEOMs operate continuously and the data averaged over one hour are assembled and transmitted to the OEH data centre for further processing and posting on the OEH website (hourly updates).

Measurement of $PM_{2.5}$

The Beta Attenuation Monitor (BAM) was chosen for the continuous measurement of $PM_{2.5}$ (Figure 28). Three BAMs are located in the UHAQMN at Singleton Central, Muswellbrook Central and Camberwell.

These instruments are fitted with size-selective inlets and very sharp cut cyclones (VSCC) to collect the $PM_{2.5}$ sample stream which is then heated (to reduce the effects of humidity) and passed through a filter tape. The amount of heating is determined by the humidity levels of the incoming sample stream.

The particles are deposited onto the glass fibre tape and then the particle mass is irradiated with beta radiation. Fine particle mass is proportional to the attenuation of this radiation through a known sample area to continuously collect and detect the measured mass.

The simultaneous mass measurements of particles on the filter tape and sample volume measurement through a calibrated orifice provide a continuous concentration measurement in micrograms/cubic metre (µg/m^3). The hourly averaged $PM_{2.5}$ data are collected and posted on the OEH website (hourly updates).

Figure 27: TEOM instrument – used for PM_{10}

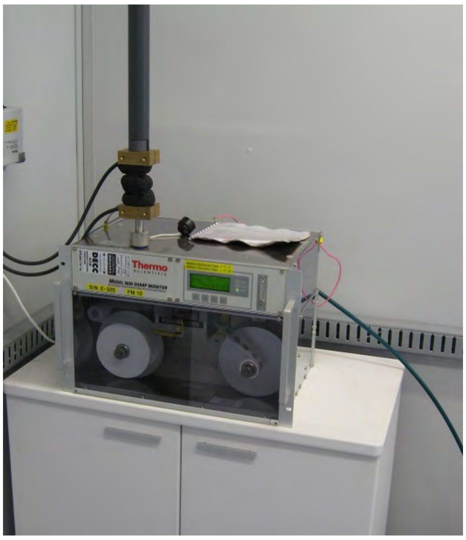


Figure 28: BAM instrument – used for $PM_{2.5}$

Photos: OEH

Appendix 7: Rainfall and temperature maps

Following are Bureau of Meteorology NSW interannual rainfall difference and rainfall and temperature deciles maps[9] for 2013 and 2012 (Figure 29 to Figure 35).

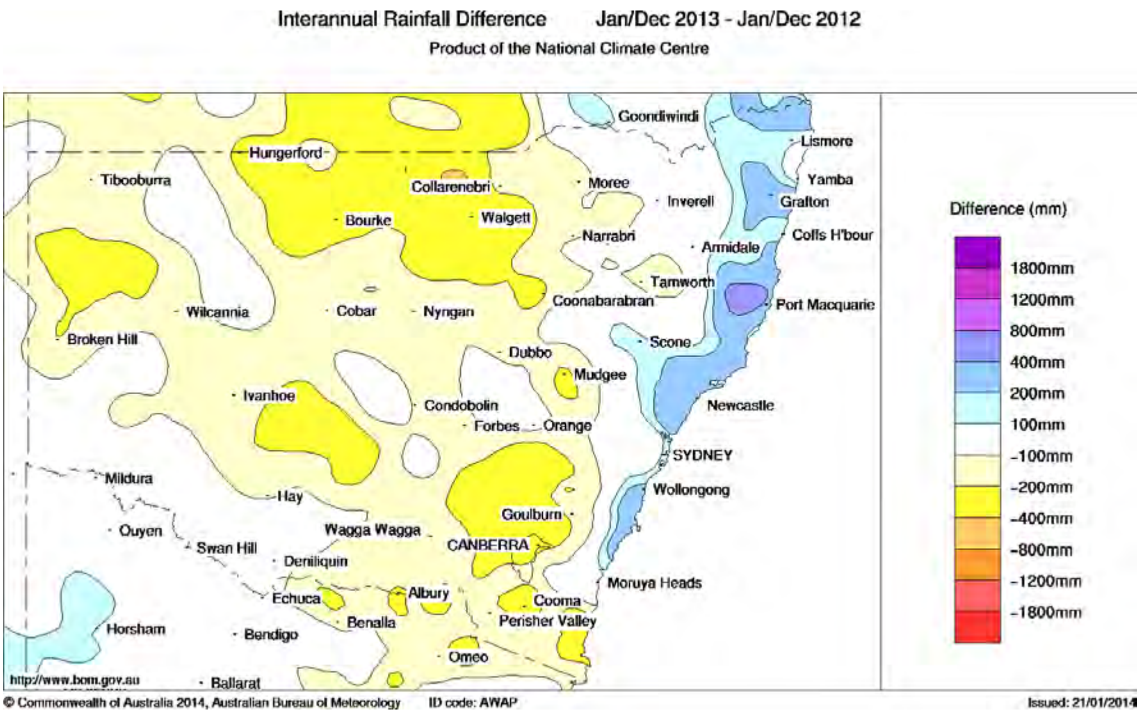


Figure 29: Interannual rainfall difference (2013 compared to 2012)

[9] Maps obtained from the Bureau of Meteorology website (www.bom.gov.au/climate/maps/) accessed in April 2014.

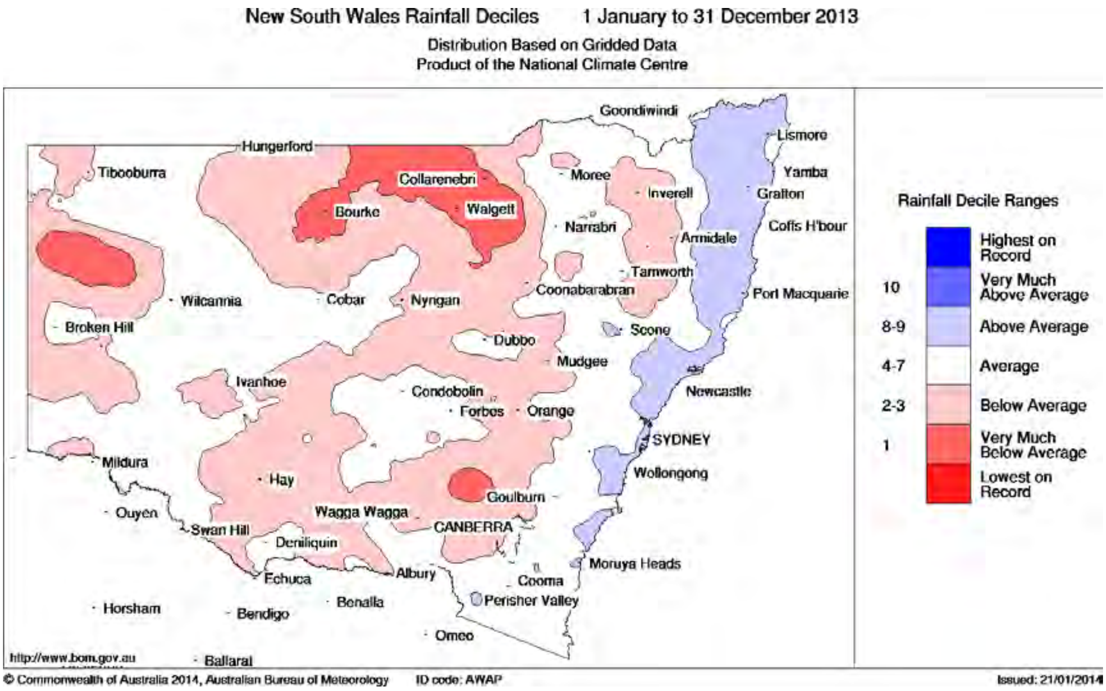


Figure 30: NSW rainfall deciles (2013)

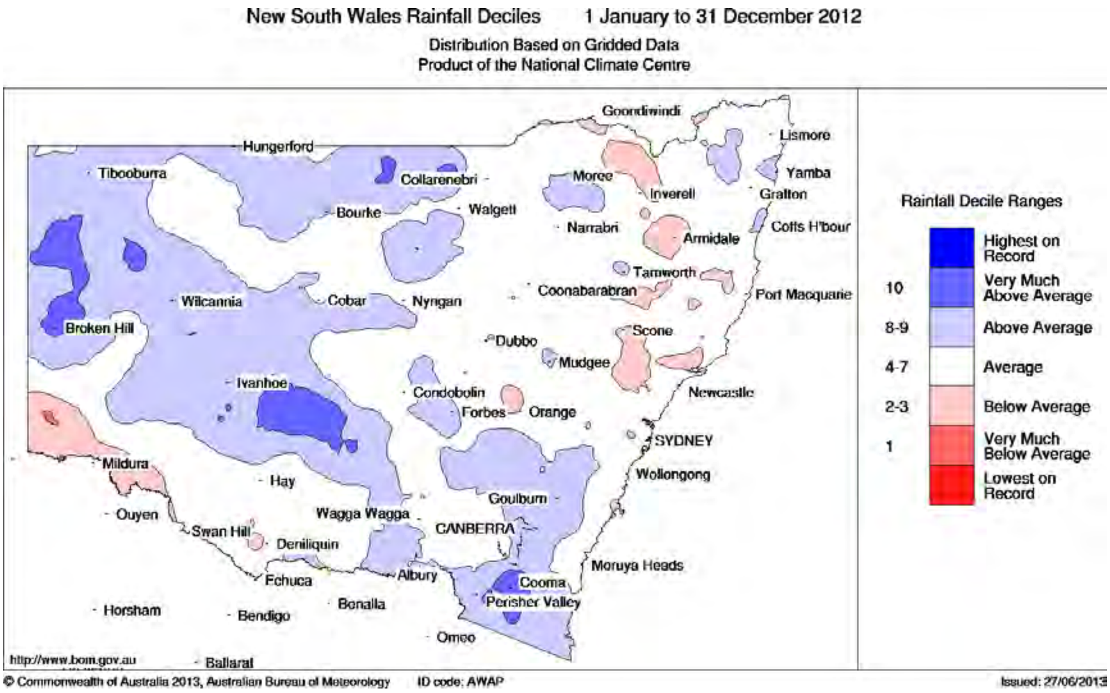


Figure 31: NSW rainfall deciles (2012)

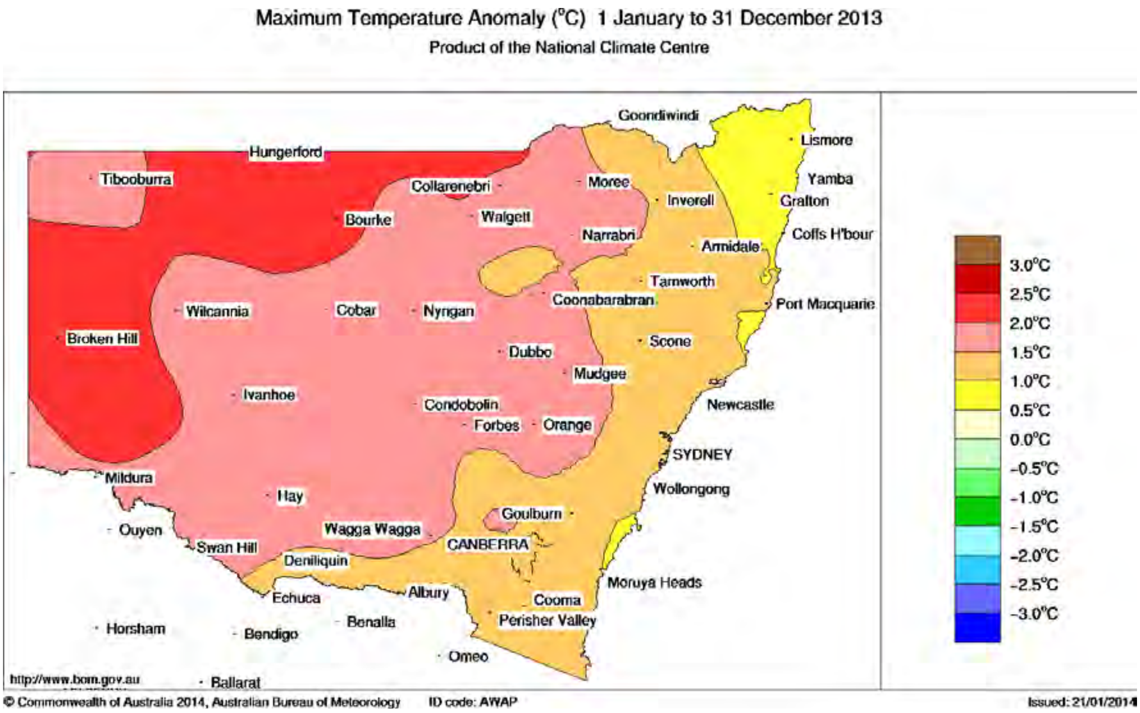


Figure 32: NSW maximum temperature deciles (2013)

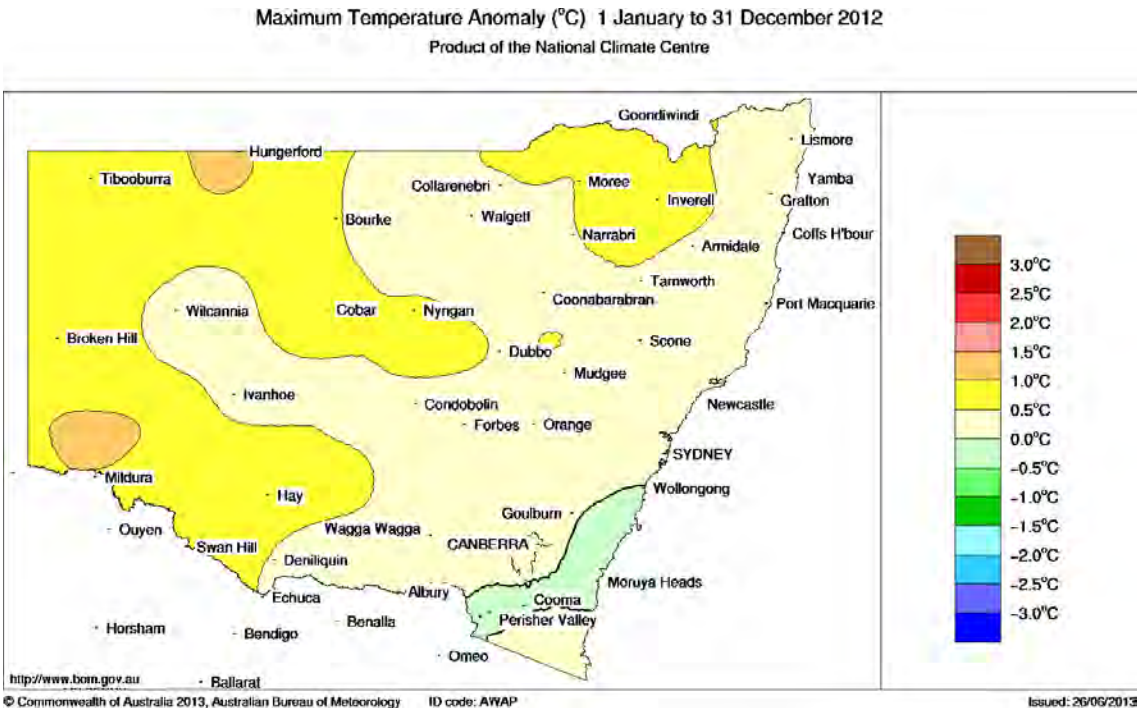


Figure 33: NSW maximum temperature deciles (2012)

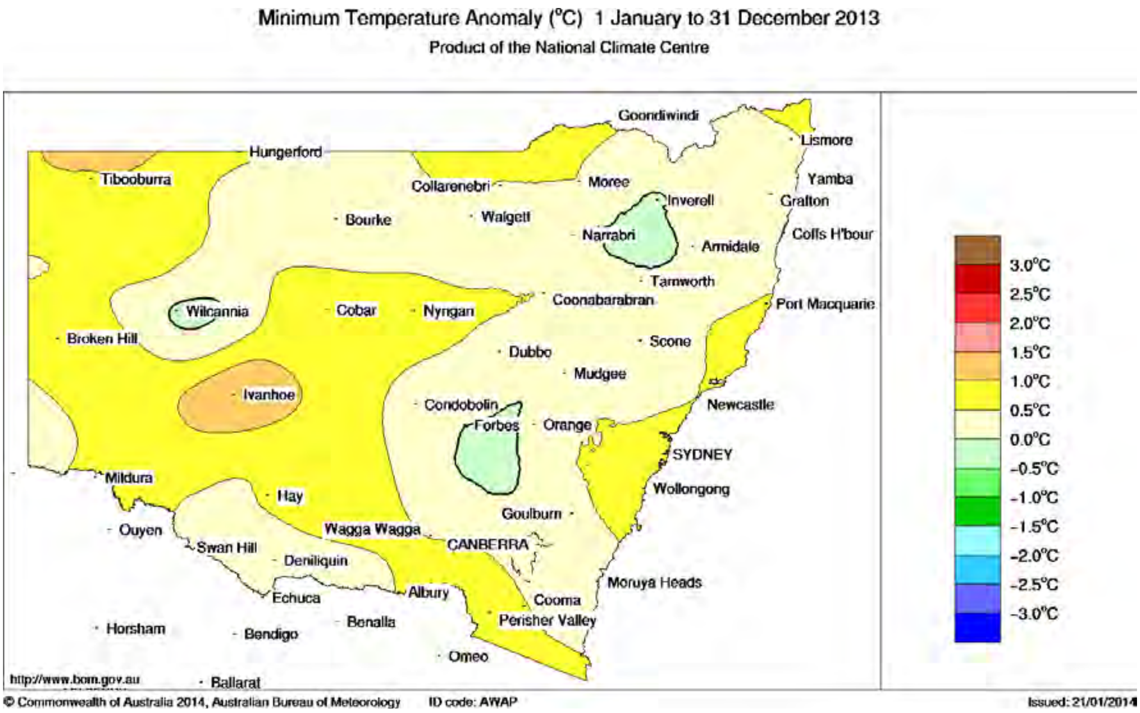


Figure 34: NSW minimum temperature deciles (2013)

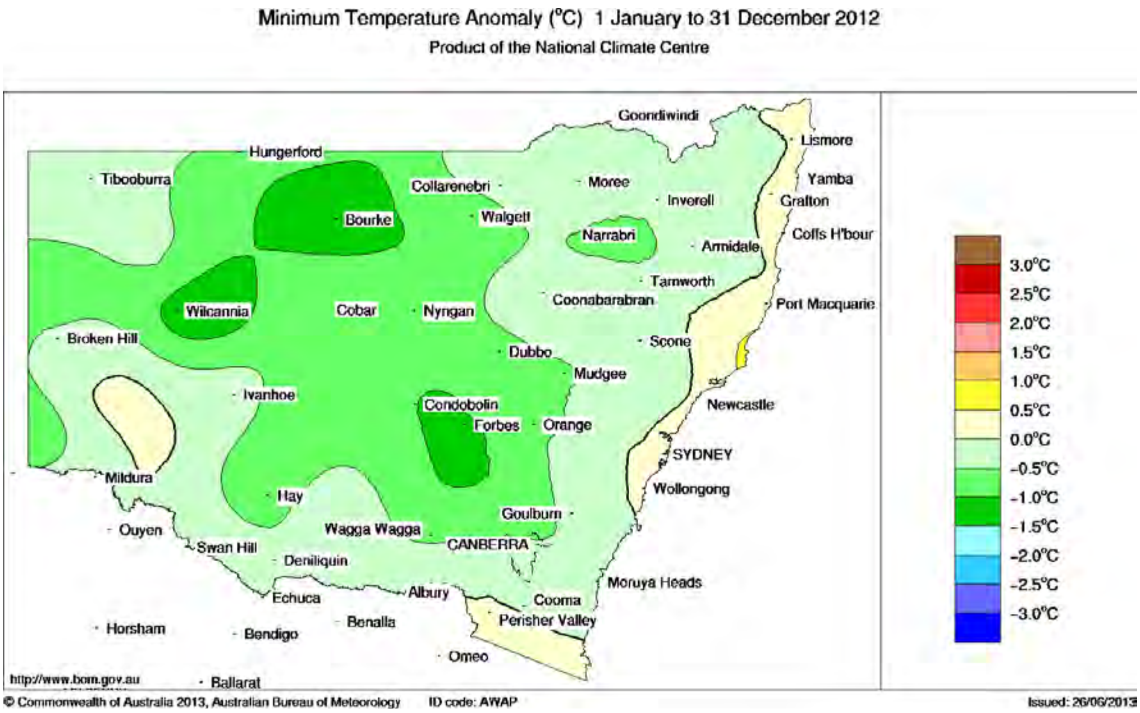
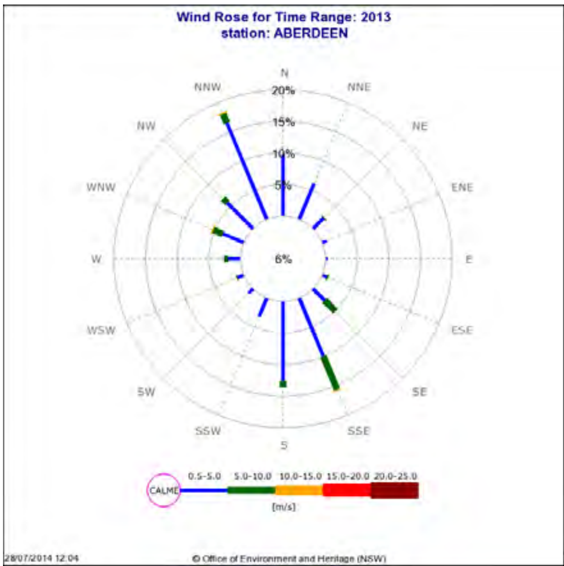
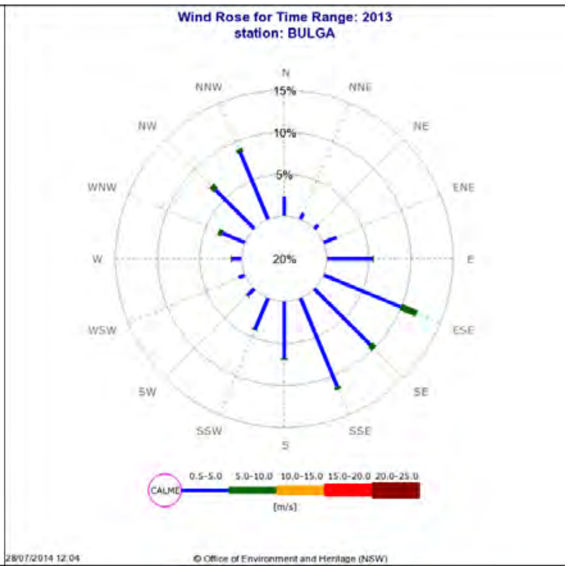
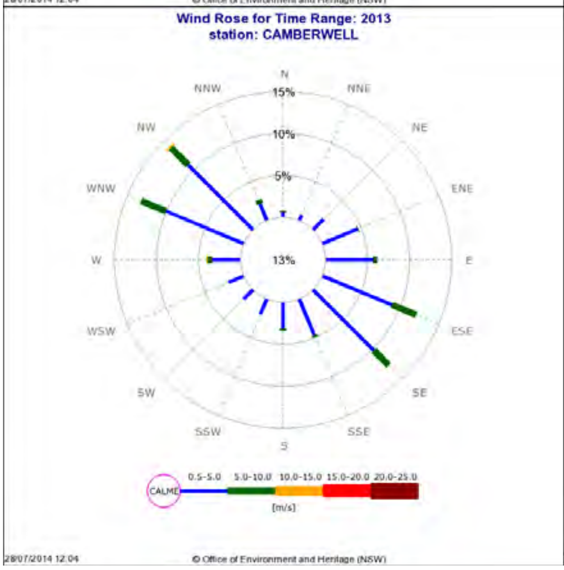


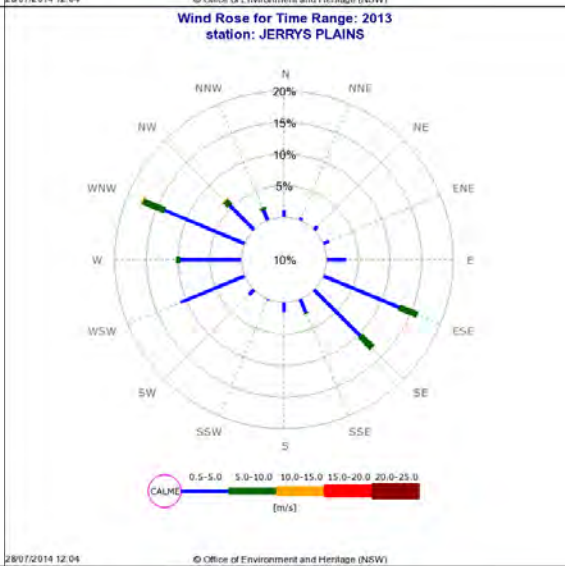
Figure 35: NSW minimum temperature deciles (2012)

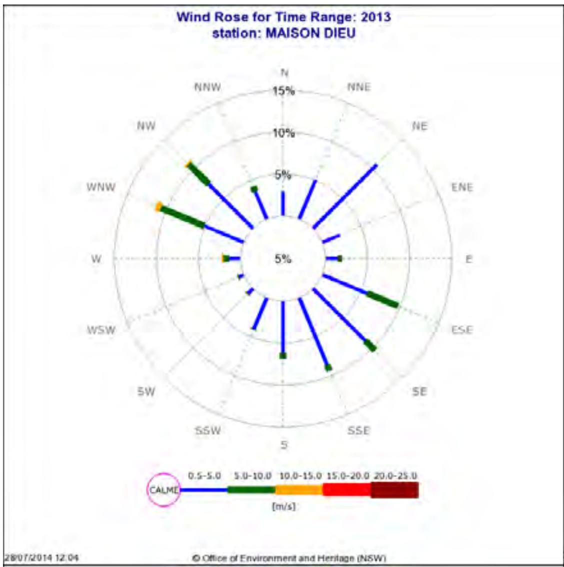
Appendix 8: Wind roses

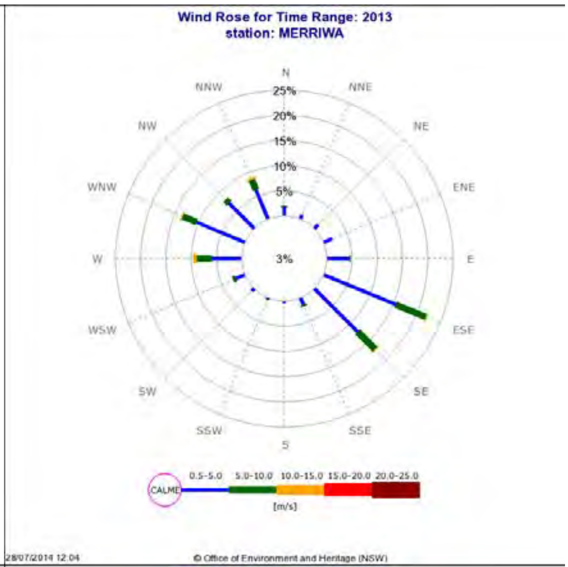


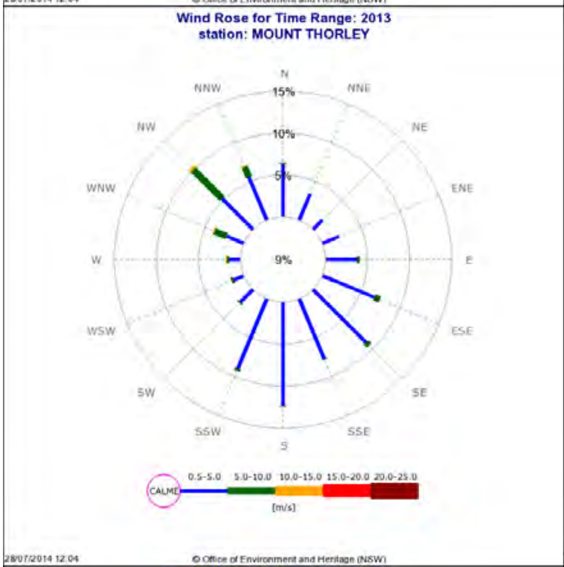


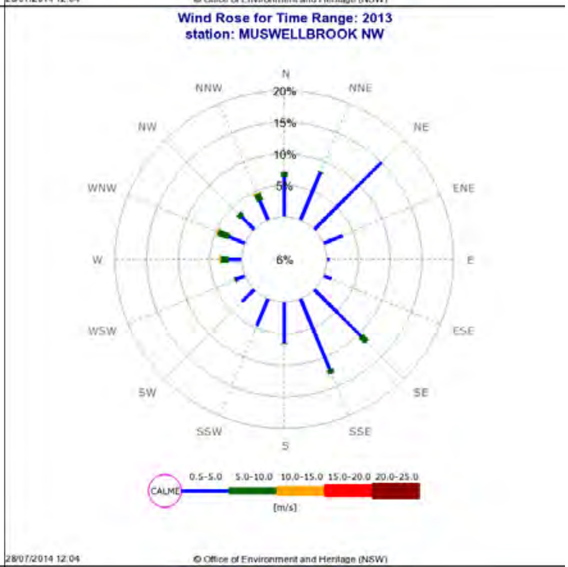


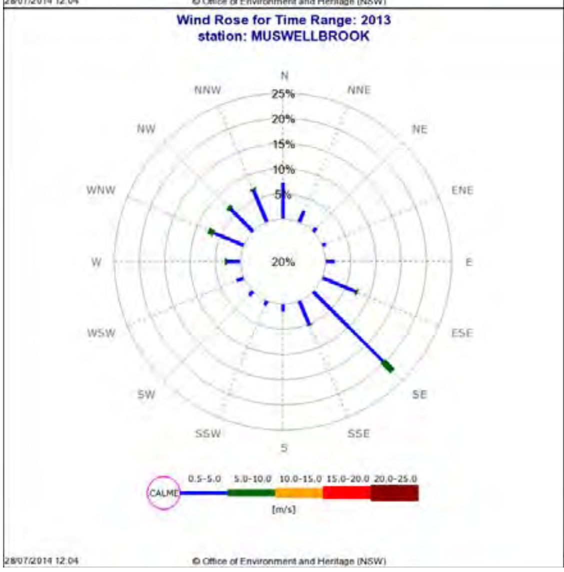


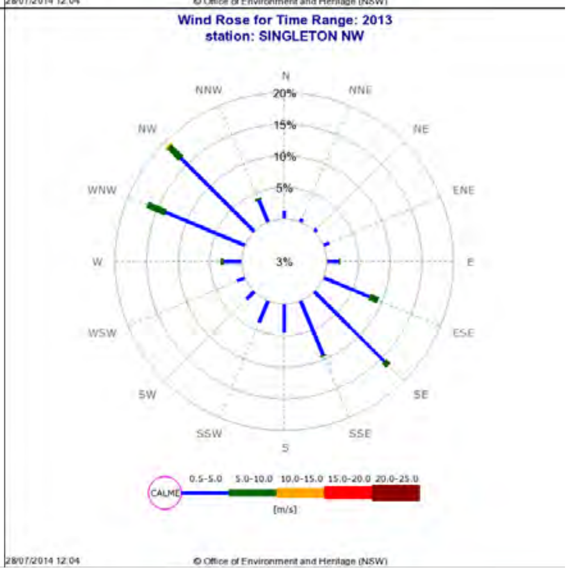

Wind Rose for Time Range: 2013
station: MAISON DIEU
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
15%
10%
5%
5%
CALMS
0.5-5.0 5.0-10.0 10.0-15.0 15.0-20.0 20.0-25.0
[m/s]
28/07/2014 12:04
© Office of Environment and Heritage (NSW)

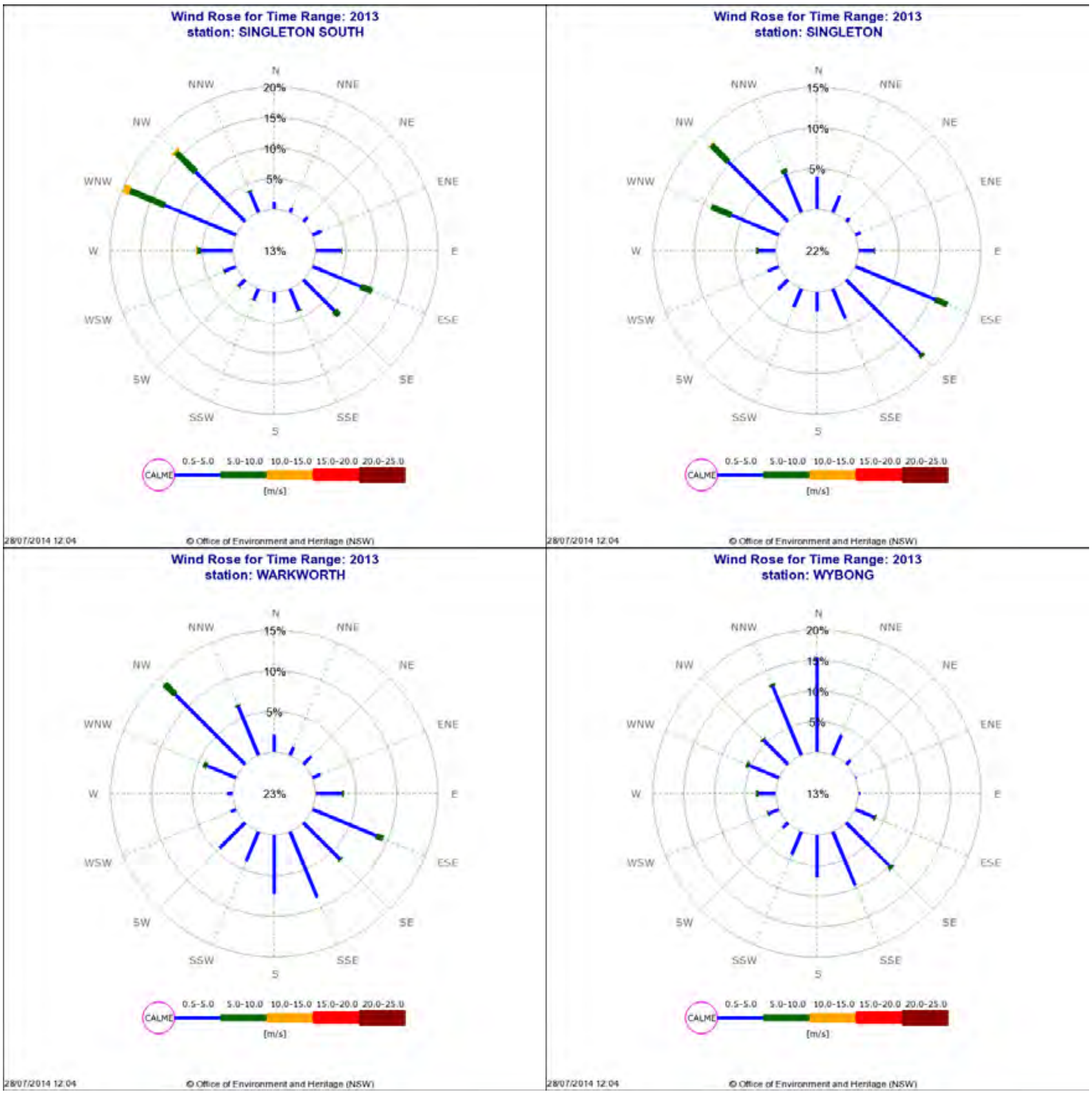

Wind Rose for Time Range: 2013
station: MERRIWA
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
25%
20%
15%
10%
5%
3%
CALMS
0.5-5.0 5.0-10.0 10.0-15.0 15.0-20.0 20.0-25.0
[m/s]
28/07/2014 12:04
© Office of Environment and Heritage (NSW)


Wind Rose for Time Range: 2013
station: MOUNT THORLEY
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
15%
10%
5%
9%
CALMS
0.5-5.0 5.0-10.0 10.0-15.0 15.0-20.0 20.0-25.0
[m/s]
28/07/2014 12:04
© Office of Environment and Heritage (NSW)


Wind Rose for Time Range: 2013
station: MUSWELLBROOK NW
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
20%
15%
10%
5%
6%
CALMS
0.5-5.0 5.0-10.0 10.0-15.0 15.0-20.0 20.0-25.0
[m/s]
28/07/2014 12:04
© Office of Environment and Heritage (NSW)

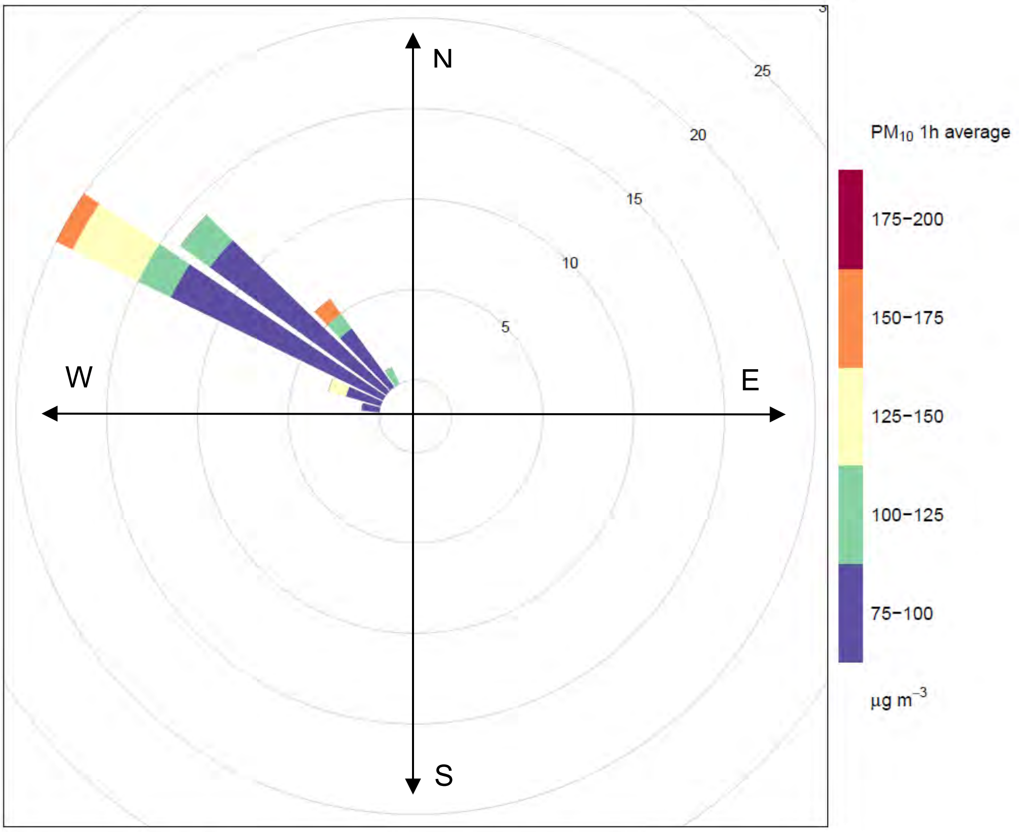

Wind Rose for Time Range: 2013
station: MUSWELLBROOK
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
25%
20%
15%
10%
5%
20%
CALMS
0.5-5.0 5.0-10.0 10.0-15.0 15.0-20.0 20.0-25.0
[m/s]
28/07/2014 12:04
© Office of Environment and Heritage (NSW)


Wind Rose for Time Range: 2013
station: SINGLETON NW
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
20%
15%
10%
5%
3%
CALMS
0.5-5.0 5.0-10.0 10.0-15.0 15.0-20.0 20.0-25.0
[m/s]
28/07/2014 12:04
© Office of Environment and Heritage (NSW)


Wind Rose for Time Range: 2013
station: SINGLETON SOUTH
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
20%
15%
10%
5%
13%
CALME
0.5-5.0 5.0-10.0 10.0-15.0 15.0-20.0 20.0-25.0
[m/s]
28/07/2014 12:04
© Office of Environment and Heritage (NSW)
Wind Rose for Time Range: 2013
station: SINGLETON
15%
10%
5%
22%
CALME
0.5-5.0 5.0-10.0 10.0-15.0 15.0-20.0 20.0-25.0
[m/s]
28/07/2014 12:04
© Office of Environment and Heritage (NSW)
Wind Rose for Time Range: 2013
station: WARKWORTH
15%
10%
5%
23%
CALME
0.5-5.0 5.0-10.0 10.0-15.0 15.0-20.0 20.0-25.0
[m/s]
28/07/2014 12:04
© Office of Environment and Heritage (NSW)
Wind Rose for Time Range: 2013
station: WYBONG
20%
15%
10%
5%
13%
CALME
0.5-5.0 5.0-10.0 10.0-15.0 15.0-20.0 20.0-25.0
[m/s]
28/07/2014 12:04
© Office of Environment and Heritage (NSW)

Glossary

Pollution rose – is another way of presenting pollutant data in relation to the wind direction recorded at the same time at a monitoring site. In the image below, wind direction data are counted for each of the pollutant categories. The colour categories represent hourly PM_{10} levels; the angle of the coloured wedges represents the **direction from which the wind is blowing** associated with each of these pollutant categories. The concentric circles show number of hours for each category (the scale for these counts is displayed at a 45° angle in the NE wind direction sector of the plot). In the image below, it can be seen that all hourly pollutant values above 75 µg/m^3 originated from the NW sector.



Number of hours with 1hr PM_{10} concentrations above 75µg m^{-3} by wind direction

Quadrants – in the pollution rose image above, refers to directions on a compass divided into four broad regions, namely:

- the NE quadrant refers to directions between 0° (North) and 90° (East)
- the SE quadrant refers to directions between 90° (East) and 180° (South)
- the SW quadrant refers to directions between 180° (South) and 270° (West)
- the NW quadrant refers to directions between 270° (West) and 360° (North).