Visualising fine particle pollution in Sydney and surrounding regions using nephelometer readings in 2000–20

Synopsis

Nephelometers have been deployed at some stations in the NSW Air Quality Monitoring Network for longer periods than other fine particle monitoring instruments such as TEOM or BAM (Figure 1). The readings from optical nephelometer monitors are referred to as visibility data in our network, being considered good indicators of smoke impact. A high nephelometer reading typically means a high reduction in visual distance, due to high concentrations of fine particle pollution.

This analysis compared visibility readings over the last 20 years with those during the bushfire period in spring–summer 2019–20. The results show that the highest nephelometer (visibility reduction) levels were often associated with smoke impacts due to bushfires and hazard reduction burns. In particular, the spring–summer 2019–20 bushfires were associated with the highest nephelometer readings on record, indicating the highest levels of fine particle pollution due to smoke and the greatest reductions in visibility, for the longest period over the last 20 years.

This study indicates that nephelometer readings from the network provide a comprehensive long-term dataset for analysing historical trends in fine particle pollution.

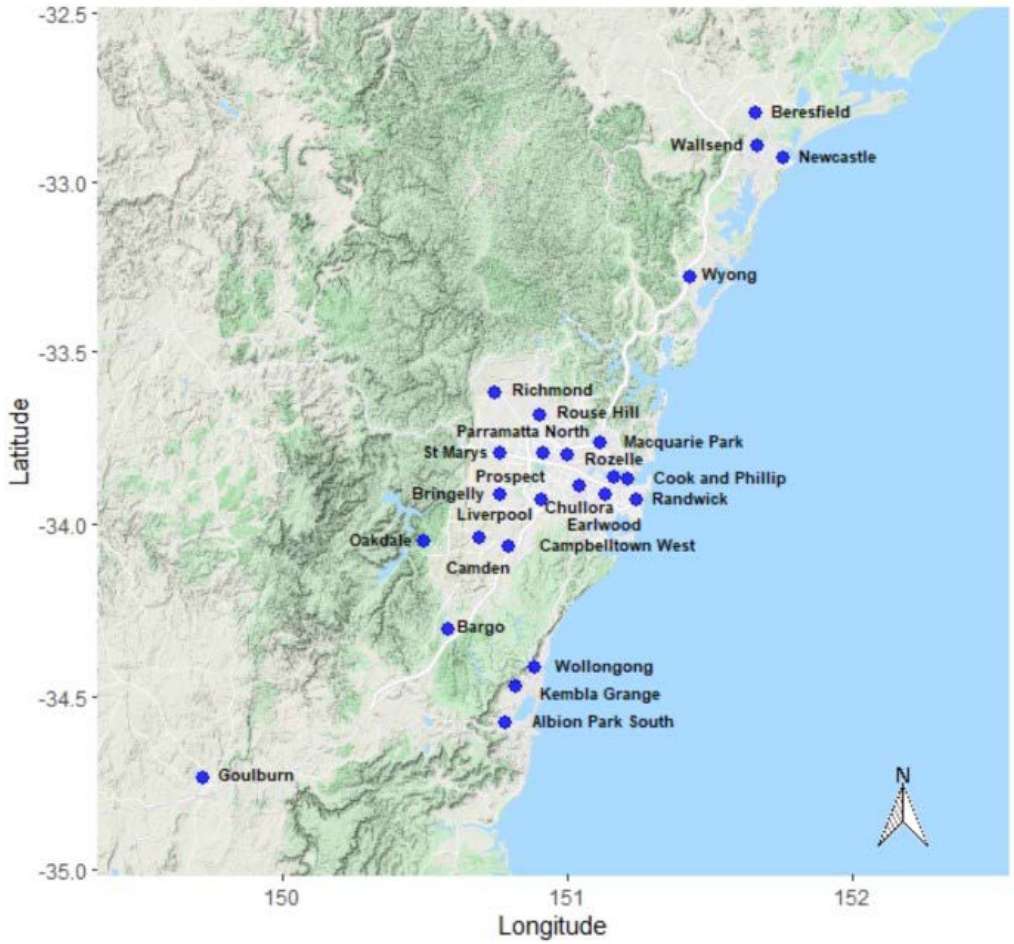


Figure 1 Air quality monitoring stations with nephelometers in Sydney and surrounding regions

Introduction

Over the last 20 years, smoke from bushfires and hazard reduction burns has contributed to about 50% of fine particle pollution measured across Sydney and surrounding regions.

Nephelometers were deployed at selected stations in the network in the 1970s. A wider rollout was conducted in the mid-1990s, and nephelometers have since been deployed at new air quality monitoring stations. Other instruments that measure fine particles, for example, BAM (Beta Attenuation Monitor), were not deployed into the network until 2012. The NSW Air Quality Monitoring Network now includes 25 stations using nephelometers to monitor changes in visibility due to fine particle pollution across Sydney and surrounding regions (Figure 1).

Readings from optical nephelometer monitors are referred to as visibility data in our network. A high nephelometer reading typically means a high reduction in visual distance, due to high concentrations of fine particle pollution. Visibility data offer a comprehensive dataset to analyse smoke impacts across Sydney and surrounding regions from 2000 to 2020.

Data visualisation

Heat map of nephelometer readings, 2000–2020

The heat map in Figure 2 displays colour-coded visibility data indicating fine particle pollution due to smoke impact, generally from bushfires and hazard reduction burns across the study area from 2000 to 2020. The heat map also includes the 'Red Dawn' dust event in September 2009, one event alone that recorded a high nephelometer reading due to fine dust particles, rather than smoke. The nephelometer measures light scattering potential due to particles in the air, referred to as scattering potential, shown in units of visibility (b_{sp}) in Figure 2.

The heat map enables the reader to quickly identify the following features of fine particle smoke events:

- intensity (high readings)
- duration (time period)
- grouping (clusters of events)
- patterns (repeating of similar events).

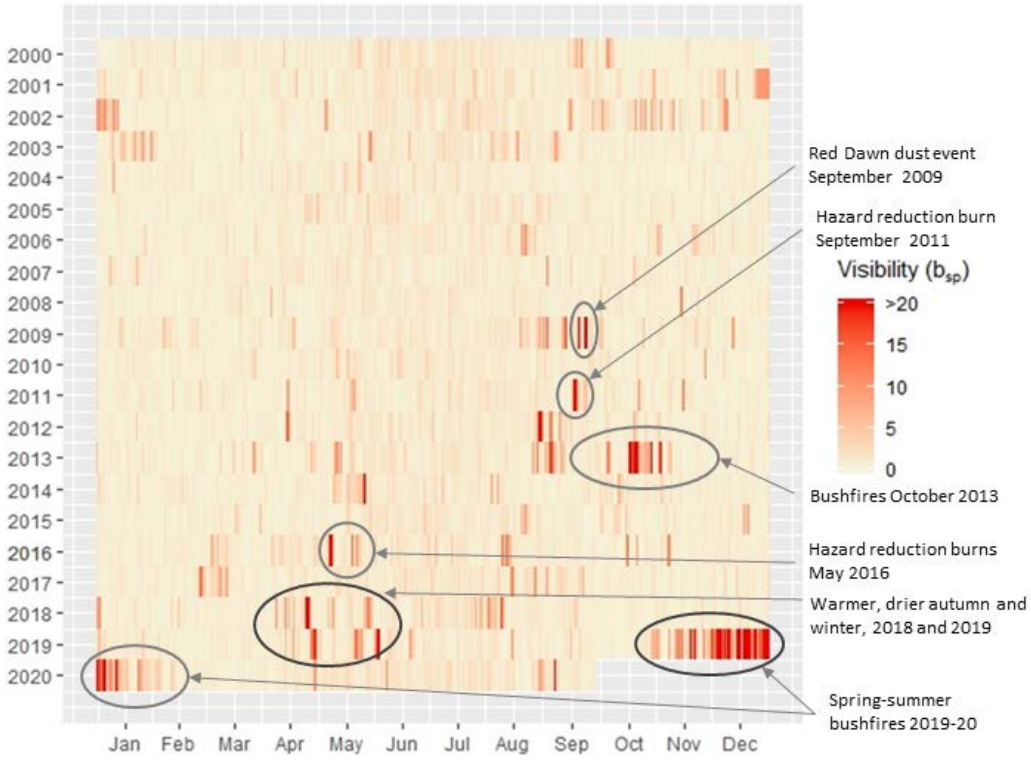


Figure 2 **Heat map of daily maximum nephelometer readings for Sydney and surrounding regions from 2000 to 2020, noting major events associated with reduced visibility indicating high levels of fine particles**

The most obvious feature of the heat map is the intensity and duration of the impact of smoke (fine particles) on visibility from the spring–summer 2019–20 bushfires (Figure 2, lower right and left). From November 2019 to January 2020, Sydney and surrounding regions recorded the most intensive and enduring period of high nephelometer readings in the last 20 years. In spring–summer 2019–20[1], the NSW Rural Fire Service (RFS) recorded the most intensive and extensive bushfire season on record, with over 880,000 hectares (ha) in forest, scrub and grass fires and over 60 ha of hazard reduction burns across Greater Sydney.

The second biggest event shown by the heat map was associated with the NSW state of emergency bushfires in October 2013 (Figure 2). From August to October 2013, RFS recorded over 78,000 ha in forest, scrub and grass fires and over 13,000 ha of hazard reduction burns[1].

An interesting pattern identified in the heat map was the increase in nephelometer readings indicating higher levels of fine particle pollution during autumn–winter 2018 and 2019, compared to the same seasons in previous years. Generally, warmer and drier autumn-winters in 2018 and 2019 were associated with greater burnt areas.

Table 1 Variations in autumn–winter climate and burnt areas across Sydney, 2016–20

Year	Seasonal climate in Sydney compared to average[2]		Approximate burnt area, hectares (ha)[1]	
	Autumn	Winter	Hazard reduction	Bushfire
2013	Equal-third warmest on record, well above average sunshine, driest on record	Warmest on record, wettest June since 2007, dry end to winter	Over 13,000 ha	Over 78,000
2016	Warmest on record, drier than average	Seventh warmest on record, wettest in 20 years	Over 800 ha	Over 7600 ha
2017	Warm and wet	Warm, wetter June, drier July and August	Over 26,000 ha	60 ha in numerous fires under 10 ha
2018	Dry, record-breaking warm	Warm and dry	Over 31,000 ha	Over 10, 000 ha
2019	Very warm, near average rainfall	Warm and dry	Over 26,000 ha	Over 900 ha
2020	Cooler, near average rainfall	Near to above average temperature and rainfall	Over 4000 ha	80 ha in numerous fires under 2 ha

During February to April 2020, the nephelometer readings (visibility reductions) were the lowest on record, indicating low fine particle pollution in the study area. Low nephelometer readings were associated with above average rainfall in February and March and fewer hazard reduction burns and bushfires compared to previous seasons[12].

Limitations of using a heat map of visibility data are noted below.

- A single localised event may affect the daily maximum value, misrepresenting regional conditions.
- The intensity of the visibility readings is masked by the data cut-off at the maximum of 20 b_{sp}.
- Visibility readings on nephelometers before 2006 had a maximum value of 10 b_{sp}, so higher readings were not recorded.
- Visibility readings cannot be directly related to the national standard for PM2.5 set by the National Environment Protection (Ambient Air Quality) Measure

Time-series of nephelometer readings, 2000–20

Time-series charts allow the reader to see the intensity of fine particle pollution reported as hourly average nephelometer readings in b_{sp} units, compared with a visibility standard of 2.1 b_{sp} (applicable at the time of data collection; since November 2020, a new threshold has been applied for current online reporting of hourly visibility data). Nephelometer readings above the standard indicate significantly reduced visibility. The time-series chart in Figure 3 identifies the highest nephelometer readings,

[1] NSW RFS ICON data base, fire incidents in Greater Sydney with over 10 hectares burnt, accessed November 2020

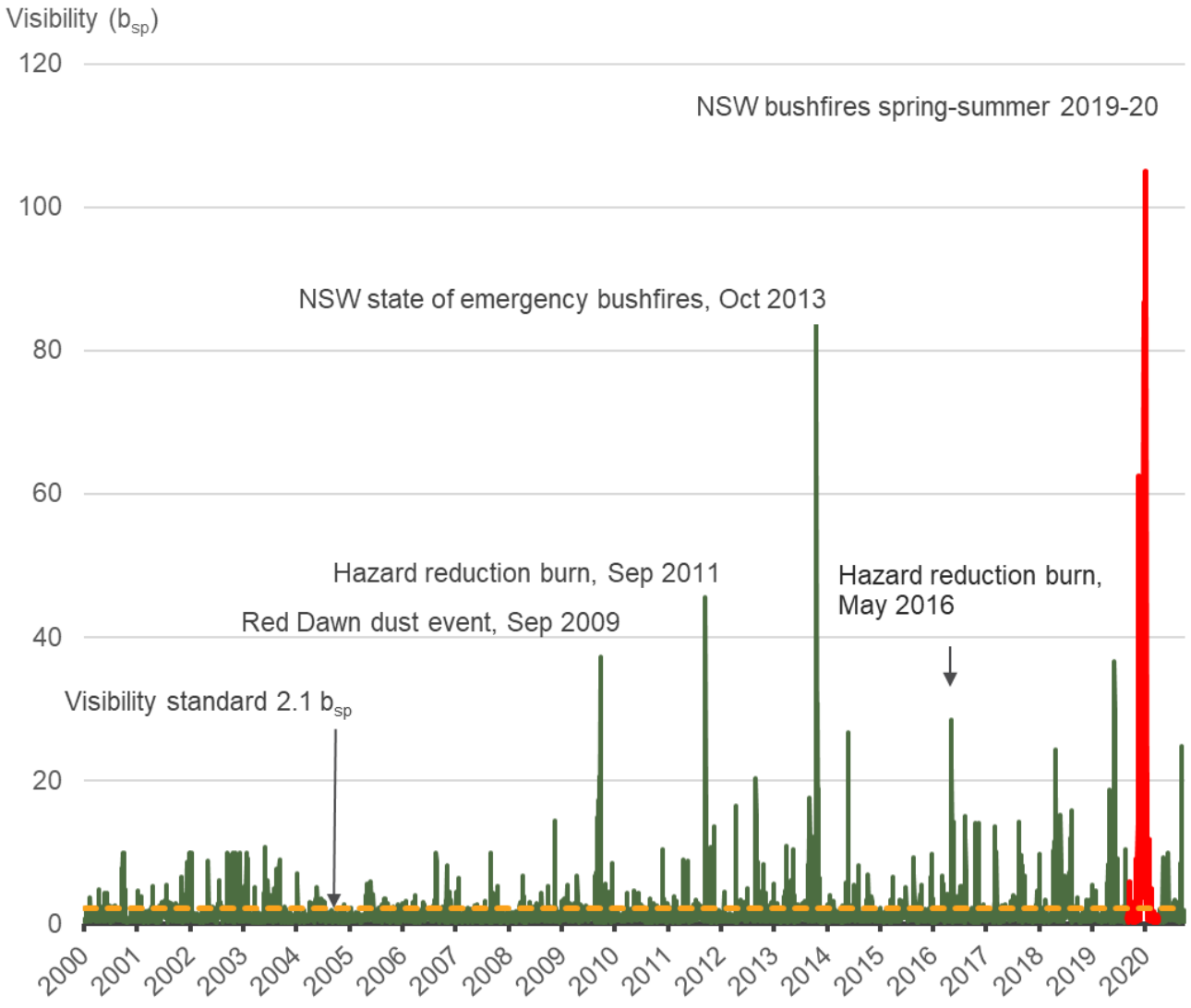
[2] Sydney seasonal climate summaries, Bureau of Meteorology, accessed November 2020

indicating the highest levels of fine particle pollution and hence the lowest levels of visibility, and associated major events in Sydney and surrounding regions from 2000 to 2020.

The summary below describes the events associated with the five highest nephelometer readings across Sydney and surrounding regions from 2000 to 2020.

- November 2019 to January 2020:
  'Black Summer' bushfires impacted south-east Australia and burnt over 5.5 million ha across New South Wales (time period identified as red in Figure 3). The highest nephelometer (visibility reduction) reading was 105.1 b_{sp} at Goulburn in the Southern Tablelands on 31 December 2019.
- October 2013, NSW State of Emergency bushfires in spring 2013:
  The highest nephelometer reading was 86.2 b_{sp} and impacted the Bargo and Campbelltown West in Sydney South West over three days in October 2013.
- September 2011, hazard reduction burning:
  The highest nephelometer reading was 45.5 b_{sp} at Bargo in Sydney South West.
- September 2009, the 'Red Dawn' dust event:
  The highest nephelometer reading was 37.7 b_{sp} at Lindfield in Sydney East.
- May 2016, hazard reduction burning in the Blue Mountains, west of Sydney:
  The highest nephelometer reading was 28.5 b_{sp} at St Marys, Sydney North West.

The 'Red Dawn' dust event in September 2009 alone had fine particles not generated from smoke. All other events were the result of fine particle pollution due to smoke.



Note: Visibility readings as nephelometer readings in b_{sp} units

Figure 3 **Time-series for daily maximum nephelometer visibility readings for Sydney and surrounding regions from 2000 to 2020. Spring–summer 2019–20 shown in red.**

Time-series of nephelometer readings, spring–summer 2019–20

Figure 4 below shows the intensity and duration of high levels of fine particle smoke and reduced visibility across Sydney and surrounding regions in spring–summer 2019–20, compared to the NSW standard for visibility (applicable at the time of data collection; since November 2020, a new threshold has been applied for current online reporting of hourly visibility data). Daily maximum visibility readings remained above the visibility standard for most of early November 2019 to mid-January 2020. In December 2019, the Gospers Mountain fire, about 200 kilometres north-west of Sydney, spread to 350,000 ha, making it the biggest forest fire in Australian history. By February 2020, the fire had amalgamated with other major fires to cover approximately one million hectares.

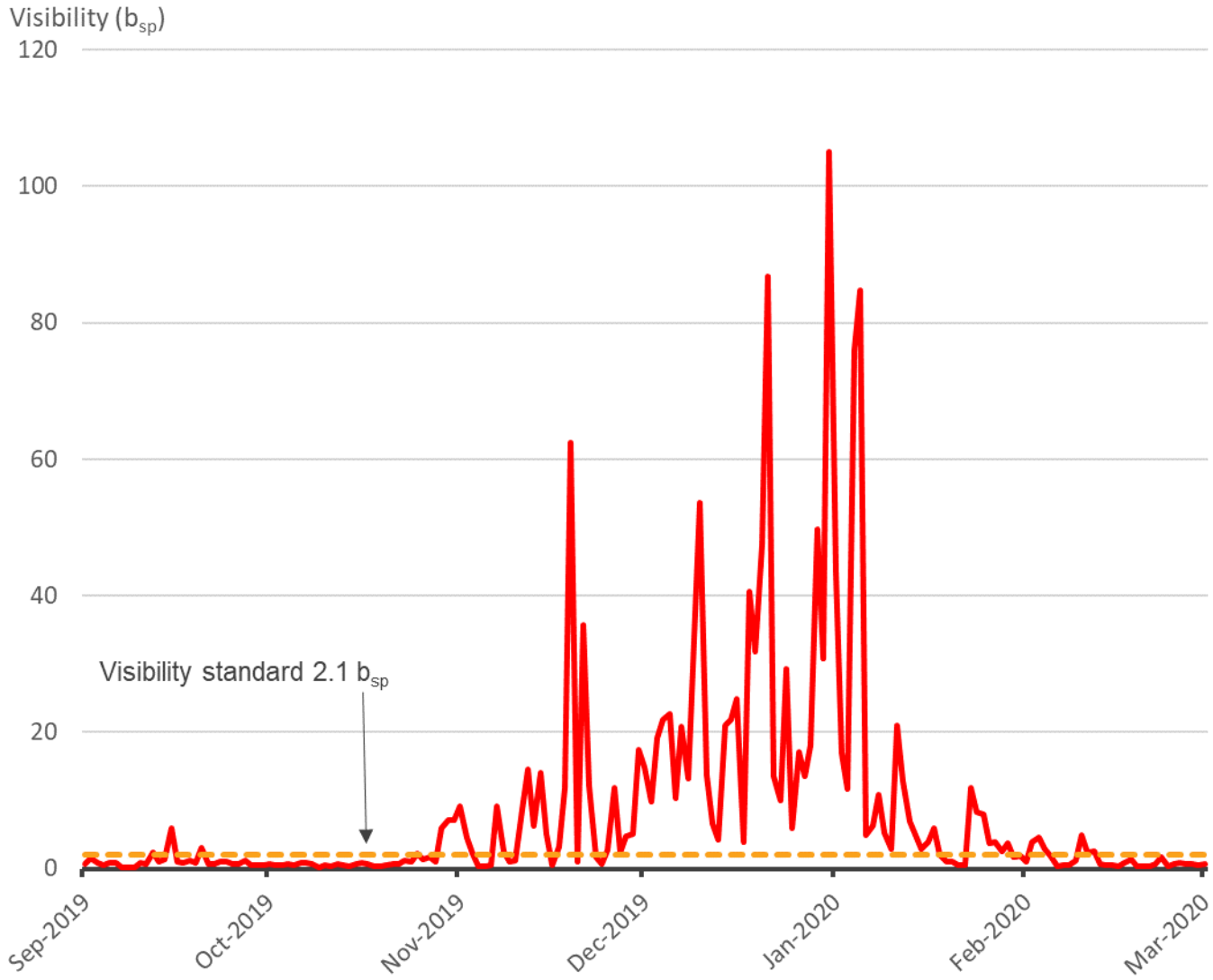


Figure 4 **Time-series for daily maximum nephelometer visibility readings for Sydney and surrounding regions from September 2019 to March 2020.**

Conclusion

This analysis has shown that highest nephelometer (risibility reduction) readings across Sydney and surrounding areas were often associated with fine particle pollution due to the impact of smoke from bushfires or hazard reduction burns.

The review of the impact of fine particle smoke from bushfires and hazard reduction burns on air quality in Sydney and surrounding regions over the past 20 years found that the highest nephelometer readings were related to the spring–summer 2019–20 bushfires. The results indicated the highest levels of fine particle pollution and the greatest reductions in visibility, for the longest period over the last 20 years. This study demonstrated that nephelometer readings from the network provide a comprehensive long-term dataset for analysing historical trends in fine particle pollution.

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