Summer ozone episode from 11 to 12 February 2017
Ozone exceedances during extreme heatwave
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Analysis of a typical ozone exceedance event in coastal New South Wales, during an extreme heatwave on 10-11 February 2017

This analysis provides some insight into the occurrence of typical high ozone pollution events in the NSW Greater Metropolitan Region (GMR). The results are useful for understanding most high ozone pollution events in coastal cities in New South Wales, including Sydney.

Event description

During 9 to 12 February 2017, New South Wales experienced an extreme summer heatwave (BOM 2017). At least 93% of the State was 10°C warmer than average, on 11 February 2017. Liverpool, in Sydney south west, recorded maximum temperatures of 44°C at 5pm on 10 February and 45°C at 5pm and 6pm on 11 February 2017. An extensive ozone pollution event occurred in coastal cities of the NSW GMR, on 10-11 February 2017 (Figure 1, Figure 2). Ozone exceeded national standards at 13 of 16 ozone-monitoring stations in the NSW GMR, including eight of 10 sites in the Greater Sydney Region (Table 1).

- On 10 February 2017, exceedances occurred at stations in four coastal metropolitan regions: Lower Hunter, Central Coast, Sydney and Illawarra (Table 1, Figure 1).
- On 11 February 2017, exceedances occurred in three regions: Lower Hunter, Central Coast and Sydney (Table 1, Figure 2). Higher 1-hour and 4-hour ozone concentrations were recorded, than on the previous day, with the highest level (13.5 pphm) at Liverpool, in Sydney south west. Longer exceedance periods were recorded, with the episode at Chullora in Sydney east persisting for seven hours (Table 1).

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Ozone exceedances in the NSW Greater Metropolitan Region, 10–11 February 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
<td>10 February 2017</td>
</tr>
<tr>
<td></td>
<td>1-hour Ozone</td>
</tr>
<tr>
<td>AQMN Station</td>
<td>start time; duration (hours); maximum concentration (pphm)</td>
</tr>
<tr>
<td>Lower Hunter</td>
<td></td>
</tr>
<tr>
<td>Wallsend</td>
<td>15:00; 1 h; 8.1</td>
</tr>
<tr>
<td>Central Coast</td>
<td></td>
</tr>
<tr>
<td>Wyong</td>
<td>14:00; 2 h; 12.1</td>
</tr>
<tr>
<td>Sydney east</td>
<td></td>
</tr>
<tr>
<td>Rozelle</td>
<td>12:00; 3 h; 11.4</td>
</tr>
<tr>
<td>Earlwood</td>
<td>17:00; 1 h; 10.9</td>
</tr>
<tr>
<td>Lindfield</td>
<td>18:00; 1 h; 10.6</td>
</tr>
</tbody>
</table>
Summer ozone episode during 11 to 12 February 2017

Region | 10 February 2017 | 11 February 2017 |
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-hour Ozone</td>
<td>4-hour Ozone</td>
</tr>
<tr>
<td>Randwick</td>
<td>15:00; 2 h; 11.6</td>
<td>15:00; 4 h; 10.2</td>
</tr>
<tr>
<td>Chullora</td>
<td></td>
<td>14:00; 1 h; 8.3</td>
</tr>
</tbody>
</table>

Sydney north west

Prospect | 14:00; 2 h; 8.3 | 15:00; 2 h; 12.3 | 15:00; 4 h; 10.6 |

AQMN Station | start time; duration (hours); maximum concentration (pphm)
| St Marys | 12:00; 2 h; 11.0 | 13:00; 3 h; 9.6 | 14:00; 2 h; 10.0 | 15:00; 1 h; 8.5 |

Sydney south west

Liverpool | 14:00; 3 h; 13.5 | 14:00; 5 h; 11.7 |

Illawarra

Albion Park South | 15:00; 2 h; 10.9 | 15:00; 3 h; 10.2 |
Kembla Grange | 16:00; 1 h; 11.3 | 15:00; 3 h; 9.4 |
Wollongong | 16:00; 1 h; 10.2 | 15:00; 3 h; 9.3 |

Notes:
1. In this case study, O₃ is measured in parts per hundred million (pphm) by volume, that is, parts of pollutant per hundred million parts of air.
2. The equivalent AAQ NEPM 1-hour ozone standard is 10.0 pphm. The 4-hour ozone standard is 8.0 pphm.

Event analysis

During 9 to 12 February 2017, a slow-moving high-pressure ridge extended north west over New South Wales from the Tasman Sea (Figure 3). On 9 February 2017, the high-pressure ridge was located over eastern NSW, providing a consistent northerly to north-westerly synoptic flow over coastal regions. On 10 to 11 February 2017, these light and persistent westerly air flows transported hot and dry inland air over coastal NSW, leading to consecutive high-temperature days over the region. By 12 February 2017, a southerly change, accompanying the passage of a slow-moving trough/cold front, brought cooler weather conditions across coastal regions.

Ground level ozone forms from interactions between sunlight and emissions of oxides of nitrogen (NOₓ) and volatile organic compounds (VOCs), from sources such as motor vehicles and industry.

The synoptic configuration on 10 and 11 February 2017 reflected typical stable atmospheric conditions conducive to elevated photochemical pollution episodes in Sydney (Figure 3, Jiang et al. 2016a). In contrast, the synoptic conditions on 9 February 2017 were not favourable for the generation or build-up of ozone pollution, due to higher wind speeds which dispersed the precursor pollutants, NOₓ and VOCs, offshore (Figure 3) (DECCW 2010, Jiang et al. 2016a, 2016b).
Summer ozone episode during 11 to 12 February 2017

Figure 1 Spatial distribution of daily maximum 4-hour rolling average ozone during 10 February 2017, showing exceedances were more intense nearer to the coast and extending to the Illawarra region (Circle sizes reflect ozone concentrations, Red shows exceedances or levels > 8pphm, and blue <= 8pphm.)
Summer ozone episode during 11 to 12 February 2017

Figure 2: Spatial distribution of daily maximum 4-hour rolling average ozone during 11 February 2017, showing exceedances were more intense in the central Greater Sydney Region. Circle sizes reflect ozone concentrations, red shows exceedances or levels > 8pphm, and blue <= 8pphm.)
Summer ozone episode during 11 to 12 February 2017

Figure 3  Synoptic charts for 11am on 9 February (top), 5pm on 10 February (middle) and 5pm on 11 February 2017 (bottom), showing a persistent high-pressure system over the Tasman Sea, extending over northeast NSW (top, green line), and drawing hot air from central Australia into coastal areas (red dot). Source: Bureau of Meteorology
Day 1, Thursday, 9 February 2017

On 9 February 2017, little ozone build-up occurred across the NSW GMR. Although conditions were hot and sunny, with temperatures above 30ºC, prevailing northerly to westerly winds dispersed ozone and ozone precursor pollutants offshore, and maximum levels reached up to six to seven ppnm only (Figure 4).

Days 2 and 3, Friday and Saturday, 10 to 11 February 2017

During 10 to 11 February 2017, synoptic conditions created hot, sunny, calm conditions across NSW coastal regions. Daytime temperatures in Sydney exceeded 40ºC. High ozone concentrations, above the one-hour and four-hour standards, occurred in the afternoons on both days, coinciding with the onset of sea breezes and their progression inland (Figure 4 a, d).

Within the Greater Sydney Region, north-easterly sea breezes converged with weaker synoptic westerly air flows, creating calm conditions and blocking air pollutants from drifting offshore (Figure 5 and Figure 6). These blocking conditions accumulated ozone and precursor pollutants along the coast. High concentrations of precursor pollutants, hot sunny conditions and maximum temperatures above 40ºC accelerated the formation of ozone. This resulted in ozone exceedances at numerous coastal stations in the NSW GMR, from the Lower Hunter in the north to the Illawarra in the south (Figure 2).

Night-time ozone was generally low, due to limited availability of sunlight and ozone precursors NOX and VOCs.

On Friday, 10 February 2017, early morning calm conditions helped the build-up of NOX levels (Figure 4 c, e). High concentrations of precursor pollutants and high temperatures (above 40ºC) accelerated the formation of ozone. Light north-westerly winds transported ozone and ozone precursor pollutants towards Sydney east. Although Liverpool in Sydney south west recorded a maximum temperature of 44ºC at 5pm (Figure 4 a), Sydney south west experienced higher wind speeds than in the east and did not record ozone exceedances. In contrast, calmer conditions in Sydney east allowed the build-up of ozone and precursors NOX and VOCs, leading to exceedances of the one-hour and four-hour ozone standards. As example, 4-hour ozone exceedances ranged from 12.1 ppnm at Earlwood to 8.1 ppnm at Wallsend (Table 1, Figure 2, Figure 4).

Five monitoring stations exceeded the one-hour and four-hour ozone standards (Sydney east: Rozelle, Earlwood, Lindfield and Randwick; Sydney north west: St Marys). Two sites exceeded the four-hour ozone standard (Sydney east: Chullora; Sydney north west (Prospect) (Table 1)).

On Saturday, 11 February 2017, local conditions were similar to the previous day, with higher temperatures across the Greater Sydney Region. Liverpool in Sydney south west recorded temperatures of 45ºC at 5pm and 6pm (Figure 4 a). The afternoon sea breezes penetrated further inland than on the previous day, transporting ozone and ozone precursor pollutants to the west. This led to the highest ozone exceedances in western regions of Sydney, with the maximum recorded at Liverpool. Elevated ozone levels persisted across the city for five to seven hours (Table 1, Figure 2, Figure 4, Figure 6).

Five monitoring stations exceeded the one-hour and four-hour ozone standard (Sydney east: Randwick and Chullora; Sydney north west: Prospect and St Marys; Sydney south west, Liverpool). Two sites exceeded the four-hour standard (Sydney east: Earlwood and Lindfield) (Table 1).
Day 4, Sunday, 12 February 2017

On Sunday, 12 February 2017, a southerly change, associated with the passage of a slow-moving cold front, brought relatively lower temperatures and higher wind speeds. Ozone levels were relatively lower across the Greater Sydney Region.
Summer ozone episode during 11 to 12 February 2017

Figure 4  Influence on ozone of low wind speeds, wind direction (calm and stable conditions), above 40°C maximum temperatures and high NO\textsubscript{X} (ozone precursor pollutant) at Liverpool, during 9-12 February 2017
Figure 5 Wind field plot for the Greater Sydney Region at 2pm on 10 February 2017, showing the easterly sea breeze and the inland westerly breeze converging near the coast. This blocking pattern persisted and combined with the calm conditions (yellow) to confine air pollution along the coast. Source: Bureau of Meteorology
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Summary

An extensive ozone pollution episode was experienced across coastal NSW on 10 to 11 February 2017, during a severe four-day heat wave. The highest one-hour ozone concentration (13.5 ppbm) was observed at Liverpool in south west Sydney on 11 February. The episode reflected the impact of local and synoptic meteorological configurations that typically lead to elevated ozone pollution in Sydney, or broadly across the NSW GMR. A slow-moving high-pressure ridge, extending north west over New South Wales from the Tasman Sea brought hot, sunny calm conditions, conducive to the formation and build-up of photochemical ozone across Sydney. Light north-westerly synoptic flows, converging with the north-easterly (afternoon) sea breezes, often determine the extent, location and duration of elevated ozone pollution in the region.

Further information on meteorology-ozone pollution relationships can be found in Jiang et al. (2016a, 2016b).
References

Bureau of Meteorology 2017, Special Climate Statement 61—exceptional heat in southeast Australia in early 2017

Department of Environment, Climate Change and Water NSW 2010, State of Knowledge: Ozone (viewed 6.6.18)
