

# The November 2016 Victorian epidemic thunderstorm asthma event: an assessment of the health impacts

The Chief Health Officer's Report, 27 April 2017



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# Foreword: Chief Health Officer

The Victorian community has experienced and endured an unparalleled epidemic thunderstorm asthma event, which has tested emergency and health services across the state and particularly in Melbourne and Geelong. This was unfortunately the largest ever recorded epidemic thunderstorm asthma event in the world and, tragically, is thought to have contributed to a number of deaths that the State Coroner is currently investigating.

This report documents the nature and impacts of the event and forms a pillar in the Department of Health and Human Services' response to plan and prepare for similar future events across Victoria. It also provides useful information and forewarning for others around Australia and the world that an epidemic thunderstorm asthma event can occur on such a scale.

I would like to acknowledge the generous collaboration and work of the Bureau of Meteorology, the Environment Protection Authority, Melbourne Pollen Count and Deakin AIRwatch in supporting the department's response to the November event and for their expert input into this report.

I would also like to express my gratitude to all emergency and health service staff for their efforts in responding to the unprecedented scale of this event. The expertise of these men and women, who assisted when called upon, each in their own way, and whose flexibility, goodwill and hard work, addressed the unique challenges of this event, and contained the level of impact to what is recorded in this report.

Finally, I would like to reflect on some of the stories I have heard describing the crowded emergency departments. Filled with patients and their families, often frightened, uncertain and unwell, these individuals acted with understanding and civility, as everyone involved began to grasp the enormity of the situation. On behalf of all service providers I would like to express my gratitude to these Victorians, whose understanding no doubt supported the staff in their efforts to respond.



**Professor Charles Guest**  
**Chief Health Officer**

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# Acknowledgements

The Department of Health and Human Services' Health Protection Branch would like to acknowledge the prompt and helpful response to our requests for data from NURSE-ON-CALL, Supercare Pharmacies, the National Home Doctor Service, Ambulance Victoria, the department's Health Service Performance and Programs Division, the Coroner's Court of Victoria and the Victorian Registry of Births, Deaths and Marriages.

The department would also like to acknowledge the substantial work of the Bureau of Meteorology, Environment Protection Authority, Melbourne Pollen Count and Deakin AIRwatch in assisting with the compilation of this report, and in both the response and planning work on epidemic thunderstorm asthma going forward.

# Executive summary

On the evening of Monday 21 November 2016, the first very hot day across the state since March 2016, Victoria experienced severe thunderstorm activity. This storm moved from the west of the state, through Geelong and across the Melbourne area. The storm was followed by an epidemic thunderstorm asthma event, the likes of which in terms of size, severity and acuity had never before been seen, nor even imagined, let alone planned for. It resulted in thousands of people developing breathing difficulties in a very short period of time, creating extraordinary and unparalleled demand across the health service system. For many of those affected this was their first asthma attack.

From 6 pm, Ambulance Victoria, hospital emergency departments, primary care providers, pharmacies and ancillary health services felt the shock of this unprecedented surge in patients with asthma symptoms and respiratory distress. The large numbers of people seeking emergency medical assistance continued throughout the night and into the next day, with hospital admissions peaking on 22 November but remaining elevated throughout the remainder of that month.

Many Victorians were directly affected with asthma symptoms, some severely, however many more were indirectly affected, with family and friends experiencing this often frightening illness. At the time of writing, the State Coroner is investigating nine tragic deaths thought to be associated with this epidemic thunderstorm asthma event.

The purpose of this report is to provide the Victorian community, health service providers, policymakers and government and non-government organisations with a record of the health impacts from this previously unimagined event. It has created a new benchmark for emergency and health service delivery that requires planning and preparation, as these infrequent but recurrent events are now known to be capable of generating an impact of such magnitude.

The key findings of this report are as follows.

## Ambulance Victoria

- There were 1,626 more calls to the Emergency Services Telecommunications Authority than forecast on 21 November 2016 (a 73 per cent increase).
- In the six hours from 6 pm on 21 November 2016, 814 ambulance cases were generated, 643 of these being 'Code 1'.<sup>i</sup>

<sup>i</sup> Code 1 emergency ambulance cases are those that require most urgent attention and a 'lights and sirens' response.



#### Emergency department presentations

- There were 12,723 presentations on 21 and 22 November 2016 to Victorian public hospital emergency departments (3,867 (44 per cent) more than expected, based on the three-year average).
- There were 9,909 presentations on 21 and 22 November 2016 to public hospital emergency departments in Melbourne and Geelong (3,643 (58 per cent) more than expected, based on the three-year average).
- This resulted in a 672 per cent increase in respiratory-related presentations<sup>ii</sup> to Melbourne and Geelong public hospital emergency departments in the 30 hours from 6 pm on 21 November 2016 (3,365 more presentations than expected based on the three-year average).

#### Hospital admissions

- There was a 681 per cent increase in asthma-related admissions to all Victorian hospitals in the 30 hours from 6 pm on 21 November 2016 (524 more admissions than expected based on the three-year average).
- There was a 992 per cent increase in asthma-related admissions to Melbourne and Geelong public hospitals in the 30 hours from 6 pm on 21 November 2016 (476 more admissions than expected based on the three-year average).
- There was a 3,000 per cent increase in asthma-related intensive care unit admissions to Melbourne and Geelong public hospitals in the 30 hours from 6 pm on 21 November 2016 (30 more admissions than expected based on the three-year average).

#### Deaths

- Nine more deaths occurred in people with asthma reported as the primary cause of death than would be expected between 21 November and 30 November 2016, based on the three-year average.
- The findings of the Coronial investigation into the circumstances of each potential thunderstorm asthma death had not yet been released at the time this report was being prepared. Asthma mortality data may change following the findings of this investigation.

#### Primary care

- There was a six-fold increase in the proportion of home visits by the National Home Doctor Service after-hours service for asthma (13.2 per cent of visits versus an average of 2 per cent).
- There was a 48 per cent increase in calls to NURSE-ON-CALL.
- There was a 2.5-fold increase in Supercare Pharmacy attendance compared with preceding weeks.

ii Respiratory presentations to emergency departments are coded as such. Those patients who had asthma but were not coded, due to time pressures at the emergency departments on 21 and 22 November, have been captured under the 'nil diagnosis' code. 'Respiratory related' presentations refer to those coded with respiratory and 'nil diagnosis' and should contain all cases of epidemic thunderstorm asthma (further detail of this grouping is provided on pages 42 and 43).

# Introduction

On the evening of 21 November 2016, following the passage of a thunderstorm across Melbourne and Geelong, unprecedented numbers of people developed asthma symptoms, some for the first time. For many, these symptoms were severe. Epidemic thunderstorm asthma events have previously occurred in Melbourne, but Victoria's health services, emergency services and the community were not prepared for an event of this scale and severity.

The event has created a new benchmark for emergency health service delivery and there is now a need for the Victorian community to prepare for future events. Broad and deep knowledge of epidemic thunderstorm asthma and relevant asthma awareness and management more generally, needs to be embedded both structurally and culturally within our community in order to ensure a sustained level of community preparedness and resilience.

This report begins by describing the current understanding of epidemic thunderstorm asthma and the environmental and meteorological conditions before and during this event. The report then presents primary care data from NURSE-ON-CALL phone service, National Home Doctor Service and Supercare Pharmacies. It also presents the impacts on Ambulance Victoria's demand, emergency department presentations and hospital and intensive care unit admissions. Finally, mortality data is discussed, with details from the Coroners Court and Registry of Births, Deaths and Marriages.

# Background

## Asthma and thunderstorms

Asthma is a common, chronic disorder affecting the airways of the lungs. People with asthma have sensitive airways that can react to certain triggers. These triggers cause intermittent narrowing of the airways (caused by bronchoconstriction<sup>iii</sup>), inflammation and swelling of the airway lining and the overproduction of mucus, resulting in airway obstruction and difficulty with breathing. Asthma triggers vary between people and include viral illness, stress, exercise, airborne allergens,<sup>iv</sup> cold air, humidity and smoke. Airborne allergens include animal hair and dander, pollen and mould (fungal) spores.

The first Melbourne-based epidemic asthma event associated with a thunderstorm was described in a letter to the editor in the *Medical Journal of Australia*<sup>1</sup> by Dr Egan, a junior resident working at the Western General Hospital. He reported that 'an asthma epidemic of 85 patients', 16 of whom required admission, occurred on 11 November (Remembrance Day) 1984. In 1992 Bellomo and colleagues<sup>2</sup> reported details of two similar asthma epidemics in metropolitan Melbourne in 1987 and 1989. The former involved 154 emergency department attendances and 26 admissions, and the latter 277 emergency department attendances and 47 admissions. The term epidemic reflected the significant and rapid increase in cases, as the average daily emergency department attendances and admissions for asthma were 26.2 and 6.2 respectively.

The best-characterised epidemic thunderstorm asthma event in Australia was in Wagga Wagga (population of 55,519) in 1997, when 215 individuals with asthma symptoms attended the emergency department of Wagga Wagga Base Hospital. Forty-one people were admitted. Almost all of these cases were later found to be allergic to rye grass.<sup>3</sup>

There is however no specific criteria defining the increase in cases required to constitute an epidemic of asthma attacks other than somewhat above what is expected. These events are highly visible to clinicians who are faced with a surge in patients and are often reported as case studies in medical literature or in the media and appear to have a distinct mechanism.

The significance of these events not only relates to the number of people affected (many for the first time), but also the rapid increase in demand for emergency healthcare that has the potential to overwhelm usual health and emergency services and may result in delayed treatment. This latter aspect requires a systemic response from health services to scale up and adapt to the immediate need.

Since 1980 there have been five reports of epidemic thunderstorm asthma events in Melbourne identified in the academic literature. These events occurred on 11 November 1984, 8 November 1987, 29 November 1989, 20 November 2003 (70 emergency department presentations),<sup>4</sup> and 25 November 2010 (36 presentations)<sup>5</sup>. A further event was reported in the media on 8 November 2011 (30 people requiring ambulance services).<sup>6</sup>

iii Bronchoconstriction is the contraction of the smooth muscle around the airways resulting in narrowing.

iv Airborne allergens are also known as aeroallergens.

Epidemic thunderstorm asthma events have also been reported in other parts of Australia (Wagga Wagga in 1997, Tamworth in 1990 and Canberra in 2010<sup>v</sup>). Worldwide, the phenomenon has occurred in Birmingham (England) in 1983 and subsequent events have occurred in England, Canada, Italy and Iran. Smaller increases in asthma presentations related to thunderstorms have been reported in studies undertaken in North America.<sup>7,8</sup>

Analysis of the event on 21 November 2016 showed it was unprecedented in size, scope and acuity compared with any previously reported local, national or international event.

The grass pollen season in Australia varies depending on the geographic location. In Melbourne, it is between 1 October and 31 December. All epidemic thunderstorm asthma events in Melbourne have occurred in November and appear to coincide with the peak grass pollen season.

In 2007 Marks and Bush<sup>9</sup> proposed that the following four conditions appear necessary for an epidemic thunderstorm asthma event to occur:

- high concentrations of allergenic material (grass pollen or fungal spores)
- a thunderstorm outflow that sweeps up bioaerosols and suspends them near ground level in population centres
- formations of respirable-sized particles (< 10 µm) via rupturing pollen grains or germinating fungal spores
- exposure of people who are sensitive to the relevant allergen and/or people who have a propensity for asthma to the air mass carrying allergenic particulate matter.

To date, most research identifies rye grass pollen as the key allergen associated with epidemic thunderstorm asthma in Victoria;<sup>2</sup> however, some evidence suggests fungal spores may also play a role.<sup>3,10</sup> Pollen production is influenced by such factors as season, grass growing conditions (such as sufficient rainfall in the preceding months) and temperature.

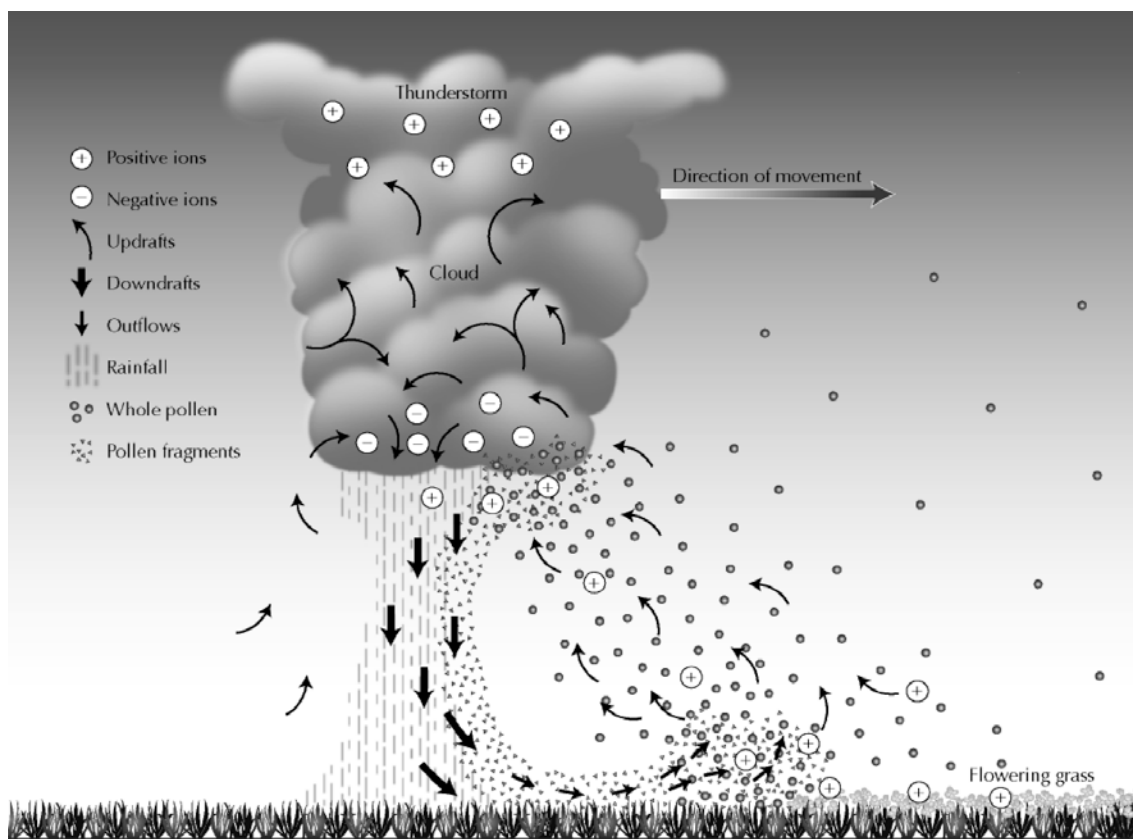
Pollen from wind-pollinated plants such as rye grass is associated with asthma and allergic rhinitis, and in Melbourne this generally peaks in November.

v A report was also identified in Canberra in the media in 2014.

## Epidemic thunderstorm asthma

Research suggests that epidemic thunderstorm asthma in Victoria is triggered by an uncommon type of thunderstorm occurring during the grass pollen season. These thunderstorms cause grass pollen grains and fungal spores to be swept up into the clouds as the storm matures (Figure 1). The pollen grains absorb moisture and may rupture due to osmotic shock, releasing a large amount of smaller allergenic particles. One pollen grain can release up to 700 starch granules that are blown down to ground level on the cold outflow of the thunderstorm and potentially across a large geographical area over a short period of time.

**Figure 1: Proposed mechanism of pollen transport and rupture during a thunderstorm asthma event**



Source: Taylor & Jonsson 2004<sup>11</sup>

The allergenic particles are small enough to get past the nose and throat and reach deep into the lungs. These particles can induce an allergic response, triggering bronchoconstriction, swelling and extra mucus production in the small airways in the lungs. This makes it difficult to breathe and results in asthma symptoms such as wheezing, chest tightness and coughing.

Certain types of thunderstorms in the right conditions are thereby able to expose large numbers of people to these potential asthma triggers and rapidly cause an epidemic of asthma.

The proposed mechanism above, is the current working model however there remain a number of questions relating to the exact role of all the prevailing meteorological conditions (such as temperature, humidity, air quality, rainfall, wind, and thunderstorm electric or lightening activity and charged particles), as well as the nature of the aeroallergens and their generation.

Only a small minority of thunderstorms in pollen season result in epidemic thunderstorm asthma. Therefore, while both thunderstorms and high grass pollen levels appear to be necessary factors in the development of epidemic thunderstorm asthma, alone these factors are not sufficient to result in an event.

### **Epidemiological risk factors – at-risk population**

Review of epidemic thunderstorm asthma events in Australia suggests that those at increased risk include people with diagnosed asthma (particularly those whose asthma is poorly controlled or who do not regularly take preventer medication), people with undiagnosed asthma and those with seasonal allergic rhinitis or a rye grass allergy. Both asthma and seasonal allergic rhinitis are common conditions in Australia, potentially suggesting a large at-risk group.

Reports suggest a large distribution in age groups of people affected by epidemic thunderstorm asthma. The majority of studies, however, report patients are most commonly younger adults, predominantly in their 20s and 30s.

Being outdoors or inside with open windows before and during the thunderstorm has been reported as a risk factor for developing asthma symptoms.<sup>3,12</sup> It also appears that those with known asthma who are taking inhaled corticosteroids may be protected.<sup>2,3</sup>

### **Asthma prevalence**

Asthma affects all age groups but particularly young people, and ranges in severity from intermittent, mild symptoms to a severe and life-threatening disorder. There is evidence that environmental and lifestyle factors (viral infections, exercise, exposure to irritants and air pollutants), as well as genetic factors such as an allergic tendency, increase the risk of developing asthma.<sup>13</sup>

The 2012 Victorian Population Health Survey (VPHS) examined the prevalence of doctor-diagnosed self-reported asthma, both lifetime and current in adults aged 18 years or over. Respondents were asked whether they had ever been diagnosed with asthma by a doctor and those who responded 'yes' were included in the estimate of lifetime prevalence of asthma.

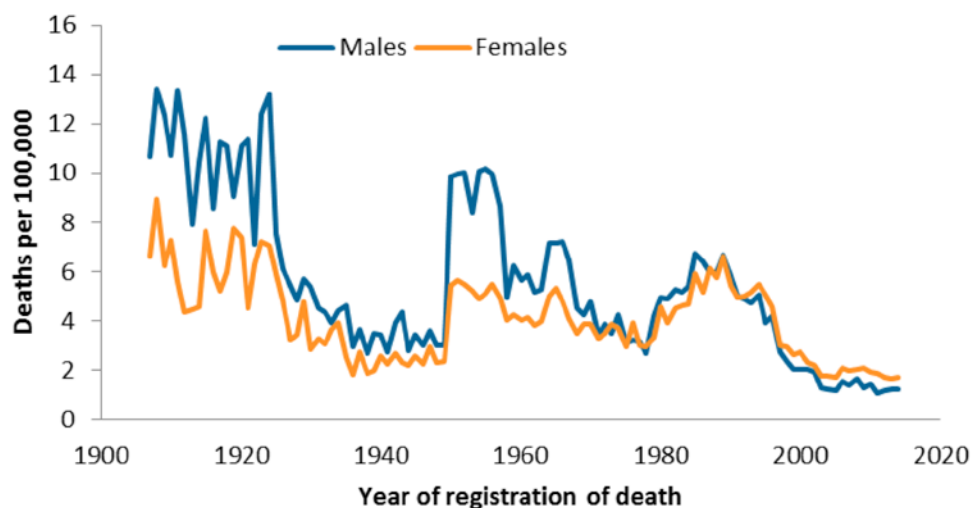
While it is difficult to quantify the burden of undiagnosed asthma in the community, in the 2012 VPHS, 21.0 per cent of men, 22.5 per cent of women (21.8 per cent of people) reported having ever been diagnosed with asthma by a doctor. There was no significant difference in the lifetime prevalence of asthma between Victorians who lived in rural and urban areas.

In total, 11.2 per cent of the adults surveyed in the VPHS had experienced symptoms of asthma, or taken treatment for asthma, in the preceding 12 months. The prevalence of current asthma has not changed significantly amongst adults in Victoria between 2003 and 2012. Of those who had experienced asthma symptoms or taken treatment for asthma in the past 12 months, 48.2 per cent reported having an asthma action plan.

The prevalence of asthma in Australian children is among the highest in the world, affecting up to 20.8 per cent of children at some point in their childhood.<sup>13</sup> About 11 per cent of boys and 6 per cent of girls aged 0–14 years have diagnosed asthma. However, from 15 years of age asthma is more common in women than men.<sup>13</sup>

In 2015, 421 people died from asthma in Australia. Asthma care was the focus of significant attention in the 1980s when mortality rose markedly. Since then, deaths have declined and mortality has remained relatively stable since 2003 (Figure 2).

**Figure 2: Age-standardised death rates for asthma, by sex and year, 1907–2014**



Source: Australian Institute of Health and Welfare 2017<sup>14</sup>

Seasonal variation in asthma is well recognised, with peaks in hospital respiratory admissions at the beginning of the school year, in the winter months and during the peak pollen season. Analysis of Melbourne public hospital admissions for respiratory conditions between 2010 and 2016 demonstrate this variation (Figure 3).

**Figure 3: Seasonal variation in respiratory admissions to all Victorian public hospitals, 1991–2015**



Source: Silver 2017<sup>15</sup>

### Allergic rhinitis prevalence

Allergic rhinitis is caused by the nose or eyes coming into contact with environmental allergens such as pollen, dust mites, moulds and animal hair. Allergic rhinitis causes a runny or blocked nose and/or sneezing and watery eyes, and is triggered by an allergic reaction. 'Hay fever' is a term commonly used to refer to allergic rhinitis caused by seasonal exposure to pollen.

Most people are familiar with seasonal hay fever, which in Australia is most commonly due to grass pollen. Large particles such as pollen, greater than 10 µm in size, can be deposited in the eyes and nose, however, are too large to penetrate the lower airway.

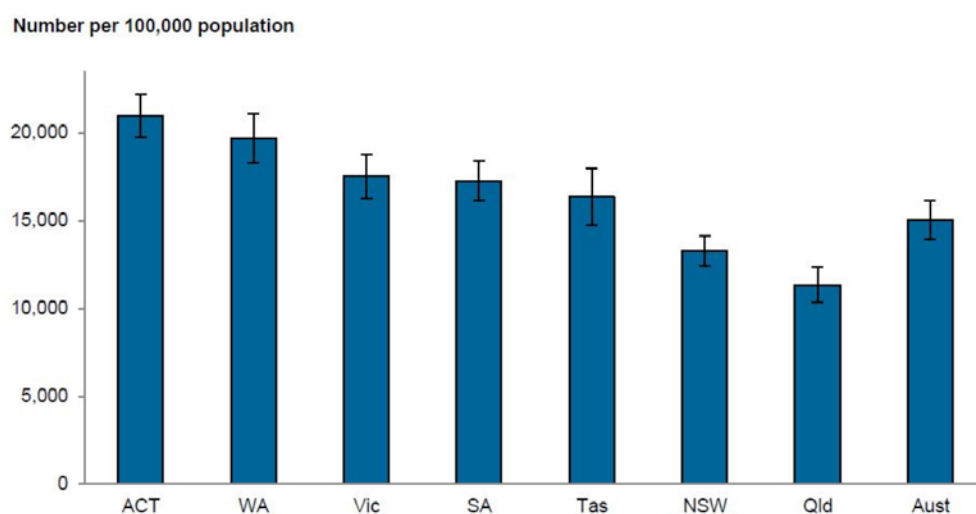


Pollens are small protein particles surrounded by an inner, cellulose-rich cell wall and a resistant outer wall. Pollens play a role in plant fertilisation. The nature and number of pollens in a particular environment varies with the vegetation, geography, temperature and climate.

The most troublesome pollen for those with allergic rhinitis tend to be airborne pollen produced by northern hemisphere grasses, trees and flowering weed species. People with allergic rhinitis are most commonly allergic to grasses that pollinate at the end of spring and beginning of summer. Pasture grasses, such as rye grass, generally trigger more allergic responses than Australian native grasses.

According to the 2007–08 National Health Survey of adults and children in Australia, overall allergic rhinitis rates in Victoria were 17,500 per 100,000 population, suggesting approximately 1.06 million Victorians may suffer from allergic rhinitis (Figure 4).

**Figure 4: Australians with allergic rhinitis per 100,000 population, by state or territory, 2007–08**



**Notes**

1. Directly age standardised to the Australian population as at June 2001.
2. Northern Territory was not included because the NHS sample size is too small for a reliable estimate.
3. The thin vertical bars attached to the top of each column are 95% confidence intervals. We can be 95% confident that the true value is within the interval depicted.

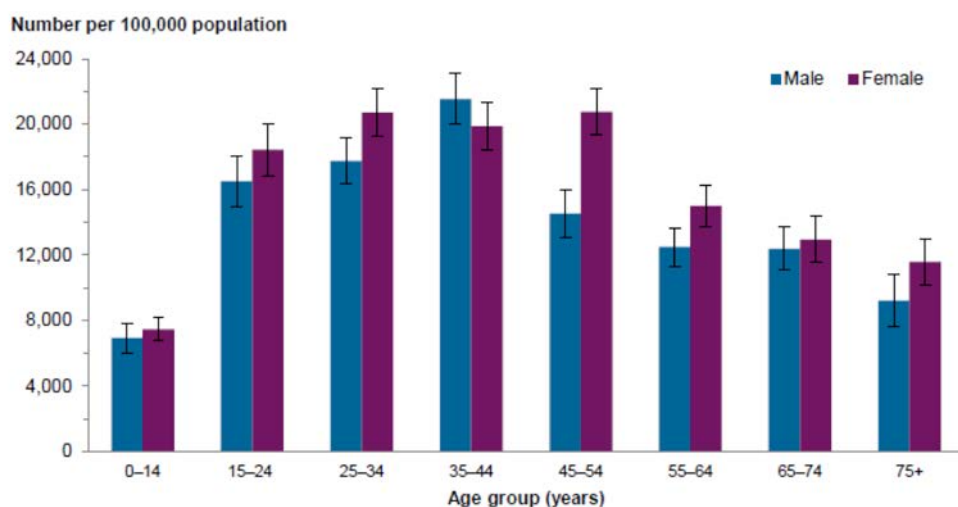
Source: Australian Institute of Health and Welfare 2011<sup>16</sup>

Allergic rhinitis is most common among those aged 35–44 (20,700 per 100,000 population), followed closely by those aged 25–34 (19,200 per 100,000 population) (Figure 5).

Allergic rhinitis is least common among the 0–14-year age group (7,200 per 100,000 population) and those aged 75 years or older (10,500 per 100,000 population).

Allergic rhinitis is more common among females in all age groups except those aged 35–44 years.

**Figure 5: Australians with allergic rhinitis per 100,000 population, by age and sex, 2007–08**



**Notes**

1. Directly age standardised to the 2001 Australian population.
2. The thin vertical bars attached to the top of each column are 95% confidence intervals. We can be 95% confident that the true value is within the interval depicted.

Source: Australian Institute of Health and Welfare 2011<sup>16</sup>

**Asthma and allergic rhinitis**

Approximately 17 per cent of Victorians have allergic rhinitis. Research suggests that in Australia 70–90 per cent of those with asthma also have allergic rhinitis, and around 50 per cent of allergic rhinitis patients also have asthma. Allergic rhinitis is an independent risk factor for developing asthma in children and adults.

While asthma and allergic rhinitis have previously been evaluated and treated as separate conditions, many now consider both are manifestations of a single inflammatory process within the respiratory tract – a ‘united airway disease’.<sup>17</sup> The main presenting symptoms vary between individuals; some experience asthma symptoms, while others experience allergic rhinitis. It is well established that treatment of upper airway disease (rhinitis) can modify the severity of lower airway disease (asthma) and vice versa.

# The approach to the assessment of the health impacts

The information for this report was sought from a variety of sources outlined below.

## Data sources

Data on environmental conditions was provided by:

- the Bureau of Meteorology
- the Environment Protection Authority
- Melbourne Pollen Count
- Deakin AIRwatch.

Data on health impact was sourced from:

- Ambulance Victoria
- the Victorian Emergency Minimum Dataset
- private hospital emergency department data set
- the Victorian Admitted Episodes Dataset
- NURSE-ON-CALL
- the National Home Doctor Service
- Supercare Pharmacies
- the Coroners Court of Victoria
- the Victorian Registry of Deaths, Births and Marriages.

Data from these sources was not immediately, nor in many cases routinely, available. Data was specifically requested from each source, who ensured its quality, including any analyses that were undertaken. Detailed analysis from NURSE-ON-CALL, Supercare Pharmacies and the National Home Doctor Service was received in December 2016 and the remainder took a number of weeks pending standard data quality assessment and analysis. To determine the impact and scale of the 21 November event, data from these sources is compared to the usual or average pattern of health service use. This allows calculation of excess or additional cases.

Comparisons can be made against many different measures of usual service usage, such as the previous week's activity, an average of the previous month or an average of the same days or dates over the previous years. The choice of comparator is determined by a number of considerations including data availability, adjustments for population growth over time and factors that may alter the usual pattern of health service use (for example a public holiday such as the Melbourne Cup or new promotion of a service). Different comparators that are clearly articulated are valid.

Specific details of each data source and the method used to determine excess cases is described in full in each of the sections that follow.

It is noted that high quality, representative data from general practice is difficult to obtain in the short term and its omission is acknowledged as an unfortunate gap in this report. Asthma is predominantly managed in general practice and it is expected that there was an increase in asthma presentations to general practices open on the evening of 21 November and on the following days.

# Findings

## Environmental conditions

### Bureau of Meteorology

The Bureau of Meteorology is Australia's national weather, climate and water agency. It provides a range of weather forecasting, warning, monitoring and advice services. In Victoria, the likelihood of thunderstorms is forecast two to seven days ahead and warnings issued when a severe thunderstorm is detected.

A severe thunderstorm is considered to be one that produces any of the following:

- large hail (2 cm in diameter or larger)
- damaging wind gusts (generally wind gusts exceeding 90 km/h)
- heavy rainfall that may cause flash flooding
- tornadoes.

Most thunderstorms do not reach this level of intensity and do not require warnings to be issued.

The bureau issues a severe thunderstorm warning when one is detected and expected to affect populated areas. These warnings typically include information on expected phenomena (for example, large hail and dangerous winds) and the area of the threat.

Forecasters use computer model predictions, data from meteorological satellites, radar displays, lightning detection networks, ground-based observations and reports from a volunteer network of storm spotters to prepare the warnings. Radar displays are key to thunderstorm forecasting because they show where, and how heavily, rain is falling.

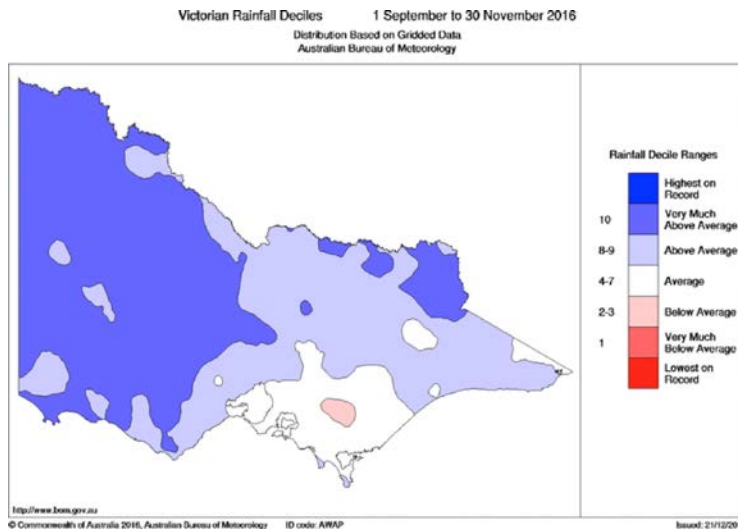
Severe thunderstorms can be quite localised and can develop quickly. The exact location of severe thunderstorms can be hard to predict. The warnings may be issued without much lead time to the event.

### Victorian weather conditions leading up to the epidemic thunderstorm asthma event

During spring 2016 Victoria's temperatures were generally close to average, with cooler than average days and slightly warmer nights.

It was Victoria's 10th-wettest spring on record, with western areas receiving very much above average rainfall (Figure 6). Record September rains were followed by a wetter than average October; however, spring ended with a generally drier than average November.

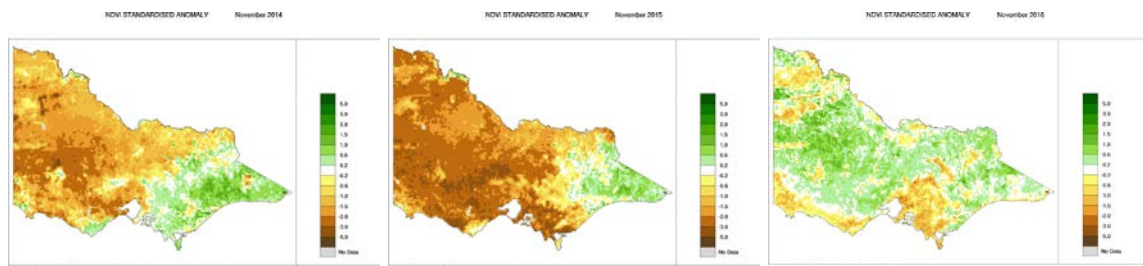
**Figure 6: Victorian rainfall deciles, 1 September to 30 November 2016**



Source: Bureau of Meteorology

Satellite-derived maps<sup>vi</sup> of Victoria show the increased vegetation both north and west of Melbourne (see Figure 7) in late November 2016 compared with the previous two years. This is consistent with the high spring rainfall in these areas.

**Figure 7: NDVI anomaly maps for November 2014, November 2015 and November 2016**



Source: Bureau of Meteorology

In the week prior to 21 November 2016, Victoria transitioned from a cool, moderate to strong southwesterly wind flow, with showers in the south of the state on 14 and 15 November, to warmer conditions by 17 November as a high pressure system moved eastwards across the state and into the Tasman. This resulted, on 17 November, in light northeasterly winds, maximum temperatures in the mid-20s in the south to mid-30s in the north of the state and no rainfall.

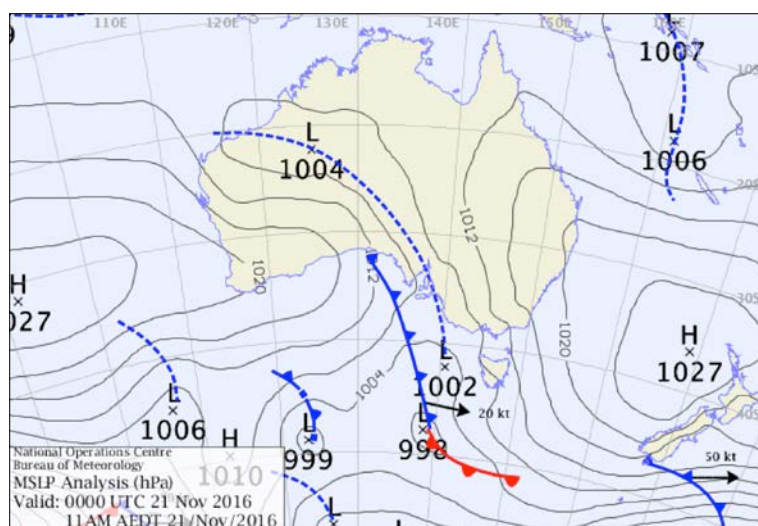
A mainly dry trough with an associated weak wind change moved across the state early on 18 November bringing cooler southwesterly winds to the south. Maximum temperatures in the north of the state still reached the low 30s. A high pressure system moved across Victoria on 19 November, resulting in light winds, no rainfall, maximum temperatures of low to mid-20s in the south and temperatures in the high 20s to low 30s in the north.

vi Normalised Difference Vegetation Index (NDVI) Standardised Anomaly maps

Northerly winds developed on 20 November, with maximum temperatures generally in the high 20s to mid-30s throughout. Thunderstorm and shower activity developed during the afternoon and evening north of a line from Corryong to Horsham and also in East Gippsland, but no significant rainfall was recorded. This activity stopped soon after midnight. Apart from locally raised humidity levels with this rainfall, Victoria did not experience any days of general high humidity levels during this week.

Victoria experienced its first very hot day since the previous summer on 21 November as a fresh and gusty northerly wind flow developed ahead of an approaching cold front (see blue-barbed lines on Figure 8). Temperatures peaked in the low 40s through the Mallee district (north-western Victoria). Elsewhere around the state temperatures generally reached the mid to high 30s, though it was a little cooler in the southwest.

**Figure 8: Weather chart for 1100 AEDT 21 November 2016**



Source: Bureau of Meteorology

A cool change entered the southwest of the state during the early afternoon bringing a west to southwesterly wind shift. Storms also developed across western and central Victoria during the afternoon, particularly near the change. Damaging wind gusts (greater than 90 km/hr) were recorded with the storms in the west of the state. A north–south line of storms developed ahead of a mid-afternoon change in the west of Melbourne.

The wind gusts associated with individual thunderstorms developed into a gust front (the boundary between these wind gusts and the surrounding air) along a north–south line just to the east of the thunderstorms.

The thunderstorms dissipated in the western suburbs of Melbourne; however, the gust front progressed eastwards through the greater Melbourne area between around 1700 and 1830 Australian Eastern Daylight Time<sup>vii</sup> (AEDT) (Figure 9).

**Figure 9: Weather observation stations in the greater Melbourne area<sup>viii</sup>**



Between 0900 AEDT and the time the gust front passed, the winds were from the north, averaging between 25 and 40 km/h, with gusts generally between 45 and 65 km/h. In the north and northeast, winds were at a maximum during the middle of the day before easing slightly; elsewhere winds slowly increased to early afternoon then remained relatively constant in speed.

The temperature increased to the high 20s by late morning and to the mid-30s by mid-afternoon. Relative humidity was around 40 per cent in the late morning throughout greater Melbourne and then dropped by mid-afternoon to 20–30 per cent. These conditions persisted until the passage of the gust front. Although the radar indicated there were some possible isolated showers near Geelong just before the gust front, no rainfall was recorded in the rain gauge prior to the change.

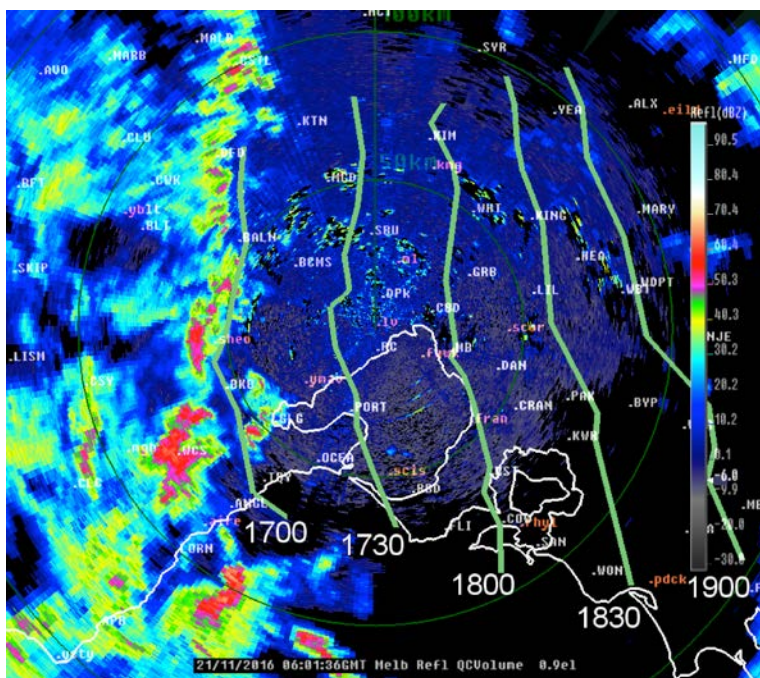
vii Australian Eastern Daylight Time is one hour ahead of Australian Eastern Standard Time (in summer Victoria uses AEDT).

viii The Greater Melbourne area, which is regarded here as the area bounded by Aireys Inlet (on the western coast just off the map), Sheoaks, Kilmore Gap (40 km north of Melbourne Airport), Coldstream and Rhyll (see Figure 9).



Figure 10 indicates the time and position of the estimated gust front as it moved across the greater Melbourne area commencing at 1700 AEDT. Weather conditions changed abruptly with the passage of the gust front and temperatures dropped rapidly from the mid-30s to the low 20s, where they remained during the evening. Winds changed rapidly from northerly winds to west or west-northwest winds with mean speeds mainly between 45 and 60 km/h and gusts of 60 to around 95 km/h. The mean wind speed on the gust front did weaken in the eastern suburbs of Melbourne; however, gusts were still reported up to 76 km/h. Across the greater Melbourne area these mean wind speeds and gusts lasted for 10–20 minutes after the initial gust front and then eased substantially to become light and variable during the evening before tending light west to southwesterly throughout late in the evening.

**Figure 10: Radar image of the thunderstorm line (indicated by easternmost areas of red and yellow) at 1701 AEDT, with the associated (1700) and subsequent (1730–1900) gust front position indicated in green**



The relative humidity values climbed rapidly with the gust front to 70–80 per cent, where it persisted most of the evening before lowering slightly as the winds tended west to southwesterly. All rainfall recorded occurred after the gust front had passed, with 1–4 mm falling on the western side of the bay and up to 1.6 mm on the eastern side.



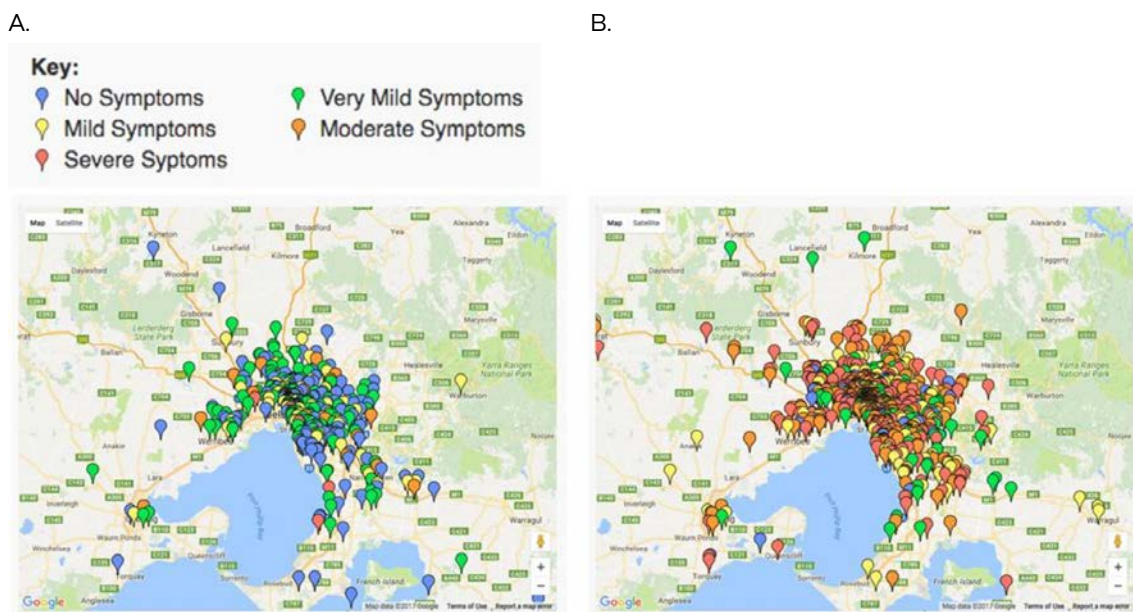
## Melbourne Pollen Count, The University of Melbourne

Melbourne Pollen Count at the University of Melbourne, Parkville, operates a pollen monitoring site that provides a daily grass pollen count and seven-day forecast during Melbourne's peak allergy period (typically 1 October to 31 December each year). The site is part of the recently established AusPollen network, a National Health and Medical Research Council-funded collaboration of seven Australian universities and partner organisations such as the Australasian Society of Clinical Immunology and Allergy, Asthma Australia, the Bureau of Meteorology and the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

Pollen counts and forecasts, historically distributed via newspapers, television and radio stations, have more recently been accessible through the Melbourne Pollen Count webpage. Since 2013 a free mobile phone app has also been available. Pollen counts are given as the average daily number of grass pollen grains per cubic metre of air for the preceding 24 hours and as a qualitative score on a scale from low to extreme.<sup>ix</sup> The pollen forecast corresponds to the expected range of grass pollen counts for that day.

The Melbourne Pollen Count phone app also lets users self-report their daily hay fever symptoms using a five-point scale. The daily average rating of hay fever symptoms helps with validating and improving the forecasting service and allows users to monitor and understand their symptoms. Figure 11 shows the high correlation that exists between the average daily hay fever symptom scores reported across Melbourne and grass pollen counts recorded at the University of Melbourne site.

**Figure 11: A. Hay fever survey data on 14 November 2016, a day with a low grass pollen count (two grains per cubic metre of air). B. Survey data on 21 November 2016, a day with an extreme grass pollen count (102 grass pollen grains per cubic metre of air)**



Source: Melbourne Pollen Count, The University of Melbourne

ix A low, moderate, high and extreme pollen count report corresponds to an average daily count of 0–19, 20–49, 50–99 and  $\geq 100$  grass pollen grains per cubic meter air, respectively.

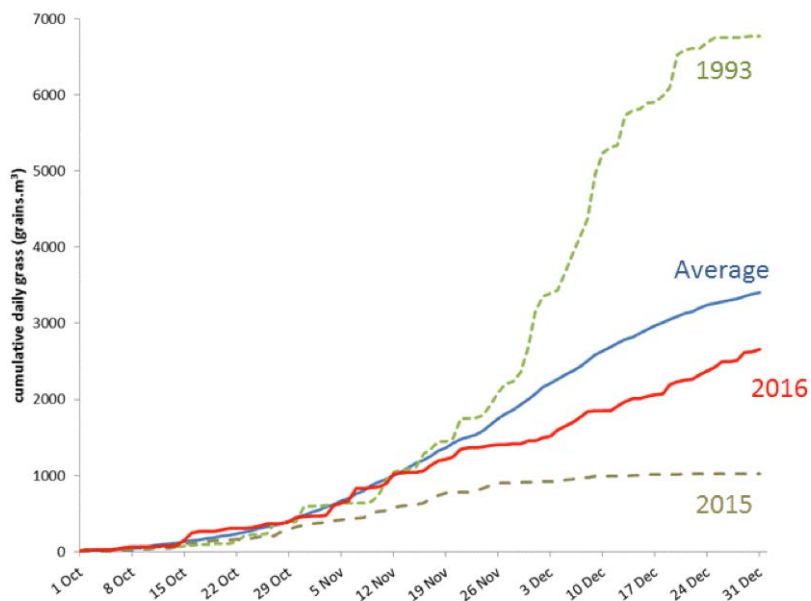
### Putting the 2016 grass pollen season in context

One way of assessing the pollen season intensity is to look at the cumulative total of grass pollen grains, which is done by adding together each daily count from 1 October to 31 December. Figure 12 shows the heaviest (1993) and the lightest (2015) grass pollen seasons on record. The first half of the 2016 pollen season closely follows the 25-year average and then declines below this from mid-November onwards.

Although the 2016 cumulative grass pollen count in November was close to the average, it was much heavier than any of the preceding few years.

The 2016 pollen season saw 14 high and six extreme grass pollen days being recorded, with the 25-year season average for these being 12 high and eight extreme days.

**Figure 12: Cumulative daily grass pollen counts for the 2016 season (red line) and two comparison seasons: 1993 (green line) and 2015 (brown line). The blue line shows the average grass pollen season (1991–2016)**



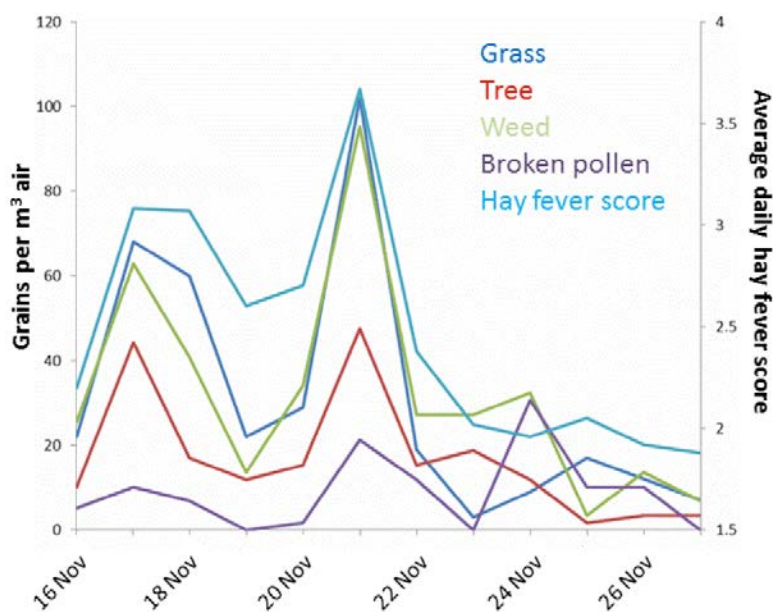
Source: Melbourne Pollen Count, The University of Melbourne

### The 21 November 2016 event

The pollen count on 21 November 2016 was 102 grass pollen grains  $\text{m}^{-3}$  of air and 147 pollen grains  $\text{m}^{-3}$  of air of all other types (see Figure 13). Pollen counts are an average across the 24-hour period to 4 pm, at which point the next counting day begins. Thus, counts for 21 November include the period from 4 pm on 20 November to 4 pm on 21 November and do not include the time when the thunderstorm passed.

As high and extreme grass pollen days in Melbourne are associated with winds from the northwest, the grass pollen level recorded on 21 November was consistent with the strong and gusty northerly to west-northwesterly winds experienced on the day.

**Figure 13: Daily pollen counts for the period 16–27 November 2016. Pollen have been classified into grass, tree and weed. Counts of broken/damaged pollen grains per day and daily hay fever scores for this period are also shown**



Source: Melbourne Pollen Count, The University of Melbourne

On 22 November, 19 grass pollen grains and 15 pollen grains per  $\text{m}^{-3}$  of air of all other types<sup>x</sup> were recorded. The line of storms that moved across Melbourne from the west during the late afternoon on 21 November brought about a change in wind direction to a light west to southwesterly and occurred soon after the start of the next counting day (4 pm on 21 November). On low grass pollen days in Melbourne the direction of the wind is generally from the southwest, and the counts recorded on 22 November were consistent with this interpretation.

Broken pollen grains detected at the Parkville site were present on most days and over the period shown in Figure 13 and were highest on 24 November.

<sup>x</sup> The main tree pollen types observed were Cupressaceae (cypress) and Myrtaceae (eucalypts and bottlebrushes), and the main weed pollen types were Plantago (plantain) and Parietaria (pellitory).

## Deakin AIRwatch at Deakin University

Deakin AIRwatch was established in 2012 as a research facility and service for staff and students who suffer from pollen allergy and asthma.

Daily pollen measurements are taken from Deakin University campuses in Burwood and Waurn Ponds in Geelong. These measurements are taken from September through to January. The pollen counts are coupled with the weather forecast to derive the pollen forecasts that are uploaded onto the Deakin AIRwatch website (<https://www.deakin.edu.au/students/faculties/sebe/les-students/airwatch>) and are publicly accessible.

The pollen numbers in the air are calculated using an air sampler that traps the pollen onto a sticky moving tape, which is removed daily at 3 pm and examined under a microscope. Total numbers of grass and other pollens, and numbers of ruptured grass pollen, on the tape can be counted.

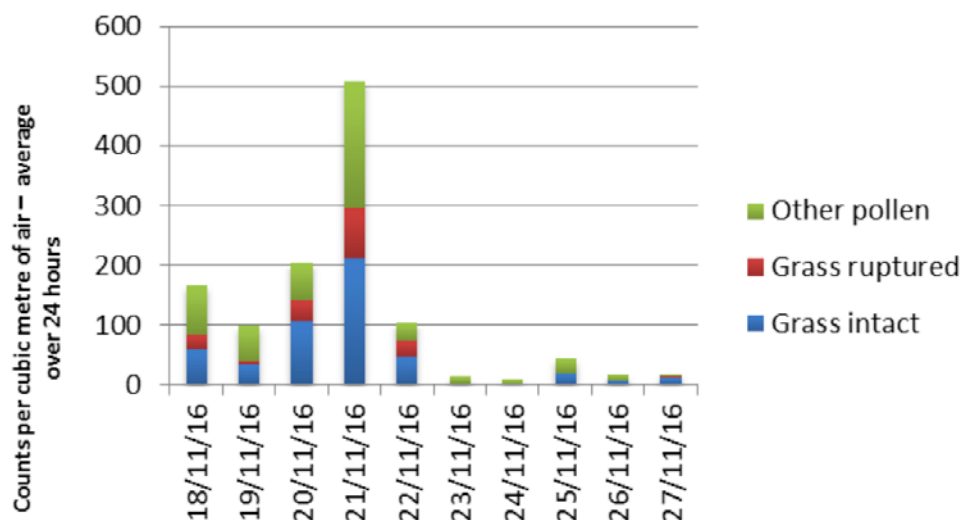
The average 24-hour pollen counts are classified into low, medium, high and extreme values reflecting 1–19, 20–49, 50–99 and  $\geq 100$  grass pollen grains per cubic meter of air, respectively, and these reflect the likely impact on hay fever.

### The 21 November 2016 event

Averaged over the 24-hour period between 3 pm on 20 November to 3 pm on 21 November 2016, the Burwood site recorded 210 intact and 86 ruptured grass pollen grains (or a total of 296 grass pollen grains) and 212 other types of pollen per cubic meter of air (Figure 14). A total of 296 grass pollen grains is considered to be indicative of an extreme-risk day for hay fever sufferers.

Between 3 pm on 21 November and 3 pm on 22 November, which included that period when the thunderstorm passed over the Burwood site, there was an average of 47 intact and 28 ruptured grass pollen grains, with 28 other types of pollen per cubic meter of air (Figure 14).

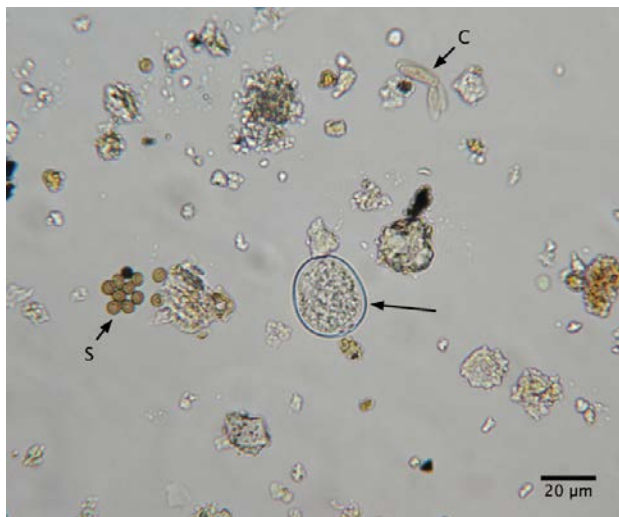
**Figure 14: Counts of intact and ruptured grass pollen grains and all other pollen in the Burwood atmosphere, averaged over 24 hours, November 2016**



The much lower average daily pollen count for 22 November was essentially all observed between 5 pm and 7 pm on 21 November, making the usual 24-hour count for the time period (which included the epidemic thunderstorm asthma event) appear surprisingly low.

The air sampled prior to the thunderstorm contained a not uncommon mix of pollen and fungal spores, likely emitted from urban grasses, trees and weeds (Figure 15).

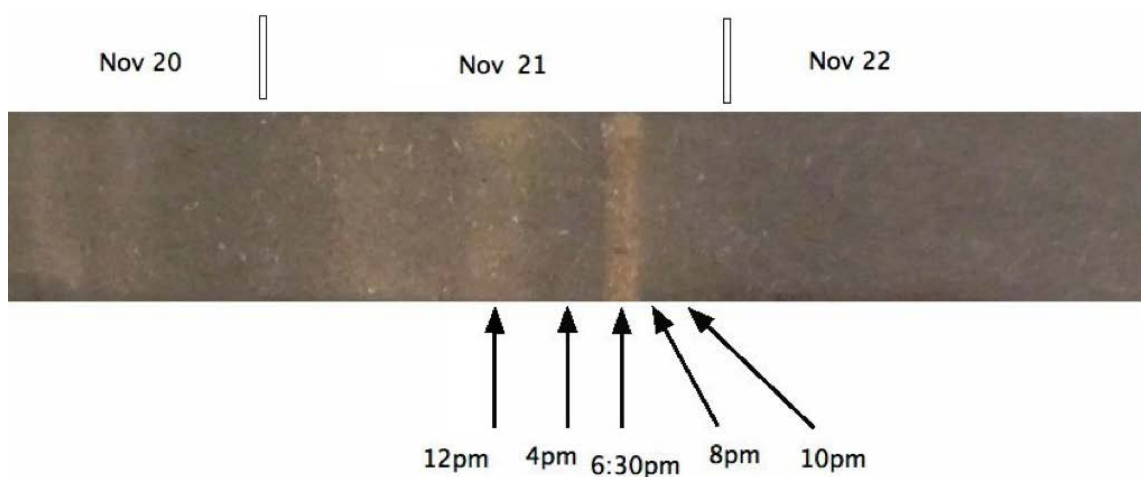
**Figure 15: Microscope image of particles collected with an air sampler at 4 pm on 21 November 2016. Grass pollen grain (arrow), *Cladosporium* conidia (C) and smut teliospores (S)**



Source: Deakin AIRwatch

The thunderstorm outflow reached Burwood at approximately 6.18 pm on 21 November, with wind speeds in excess of 60 km/h. At that time, peak airborne particles were found adhering to the pollen trap tape (Figure 16).

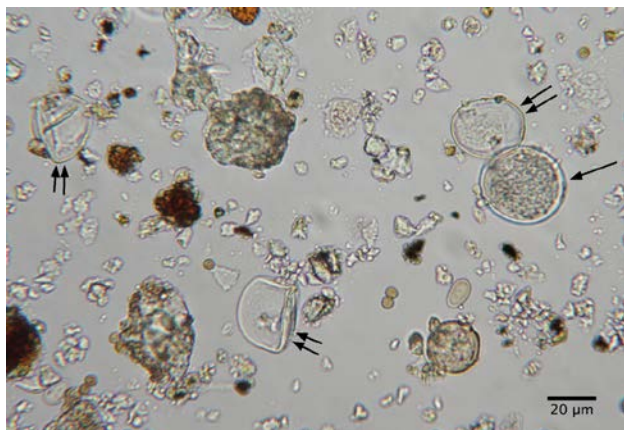
**Figure 16: Pollen trap tape collected from 20 November to 22 November showing a peak in particles**



Source: Deakin AIRwatch

A few minutes after the storm front passed, the first large raindrops began to fall, scrubbing the pollen grains from the air (Figure 17).

**Figure 17: Microscope image of air sample at 6.30 pm on 21 November. Ruptured grass pollen (double arrows) and intact grass pollen grains (arrow)**



Source: Deakin AIRwatch

In order to better describe the change in pollen count as a result of the thunderstorm, the pollen counts between 5 and 7 pm were measured each hour. This revealed a change from an average of 320 total grass pollen (207 intact, 113 ruptured) and 92 other pollen types occurring between 5 and 6 pm to 543 total grass pollen (264 intact, 279 ruptured) and 402 other pollen types per cubic meter air occurring on average between 6 and 7 pm (Table 1).

**Table 1: Hourly pollen counts between 5 and 7 pm on 21 November 2016. BEFORE refers to the hour before the storm and DURING refers to the hour during the storm**

Time period: 21 Nov	Hourly average – intact grass pollen (IGP)	Hourly average – ruptured grass pollen (RGP)	Hourly average – total grass pollen (TGP)	% total ruptured – TGP/RGP	RGP/IGP	Hourly average – other pollens (OP)	TGP/OP
5–6 pm BEFORE	207*	113*	320*	35%	0.55	92*	3.48
6–7 pm DURING	264*	279*	543*	51%	1.06	402*	1.35
% increase	28%	147%	70%			337%	

\* Note: The measurement units for these figures are number per cubic meter of air.

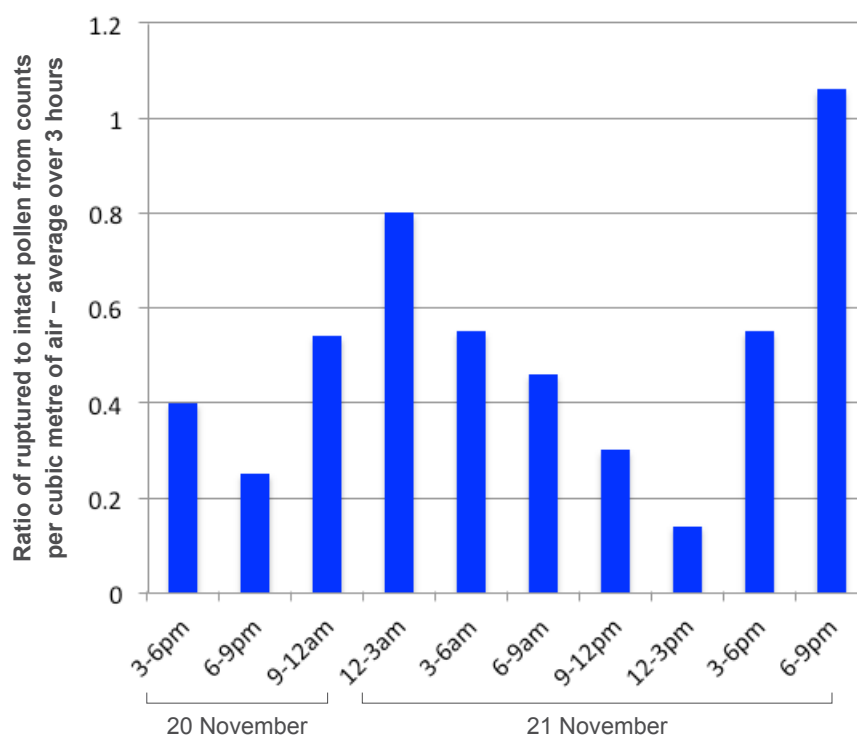


This is a 28 per cent and 147 per cent increase in the hourly average number of intact and ruptured pollen, respectively, in the hour before the storm compared with the hour during the storm (Table 1).

Given there was little grass pollen measured after 7 pm, and that rain fell soon after 6.30 pm removing pollen from the air, the hourly average of pollen counts calculated between 6 and 7 pm will underestimate the number of pollen grains during the passage of the storm outflow.

For each day of November in 2014 and 2015, on average approximately 32 per cent of the grass pollen sampled from the air were ruptured,<sup>xi</sup> with maximum counts of ruptured grass pollen not exceeding 42 per cubic meter of air over a 24-hour period. This compares with the 51 per cent of grasses being identified as ruptured and maximal counts reaching 279 per cubic meter of air averaged between 6 and 7 pm on 21 November 2016 (Table 1 and Figure 18). The ratio of the hourly average ruptured to intact pollen count in the hour prior to and after the thunderstorm changed from 0.55 to 1.06 (Table 1).

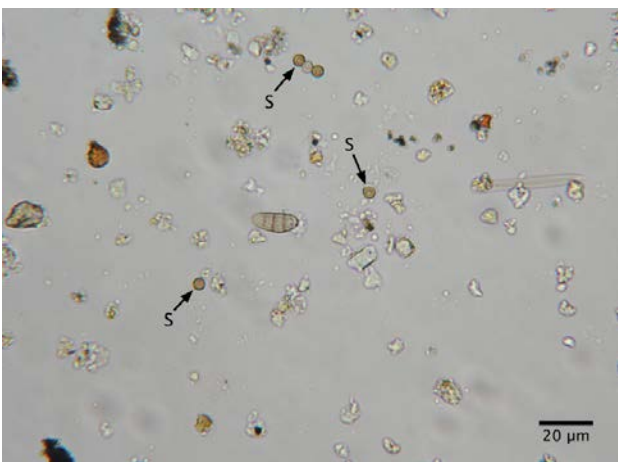
**Figure 18: Comparison of ruptured and intact grass pollen counts averaged every three hours in Burwood, 20–21 November**



xi This pollen rupture is thought to take place during moist weather events and mainly occurred on the anthers of local grasses. The contents of ruptured grass pollen can be released into the atmosphere as respirable allergen-loaded particles with the potential to trigger asthma in susceptible people.

Prior to the storm there were relatively low levels of typical dry weather fungi,<sup>xii</sup> but by 7 pm there was a predominance of smut<sup>xiii</sup> fungal spores consistent with these spores having arrived at the Burwood sampler towards the end of the outflow, when raindrops were selectively scrubbing larger particles (including pollen) from the atmosphere (Figure 19). The persistence of smut at the end of the outflow is consistent with having been transported a long distance from pastures.

**Figure 19: Microscope image of atmospheric particles and fungal spores collected at 7 pm on 21 November – smut teliospores (S)**



Source: Deakin AIRwatch

After 8 pm, and through to the morning of 22 November, no further pollen grains were observed, and very few smut spores were detected (Figure 20). The air was dominated by *Leptosphaeria* ascospores and yeast-like conidia. These are typical wet weather fungi, and were most likely emitted from local *Eucalyptus* trees and grasses.

**Figure 20: Microscope image of air sample at 8 pm on 21 November. *Leptosphaeria* ascospores (arrows), algal cells (green) and yeast-like conidia (double arrows)**



Source: Deakin AIRwatch

xii Fungi such as *Cladosporium* conidia, rust urediniospores, and basidiospores from coprinoid mushrooms.

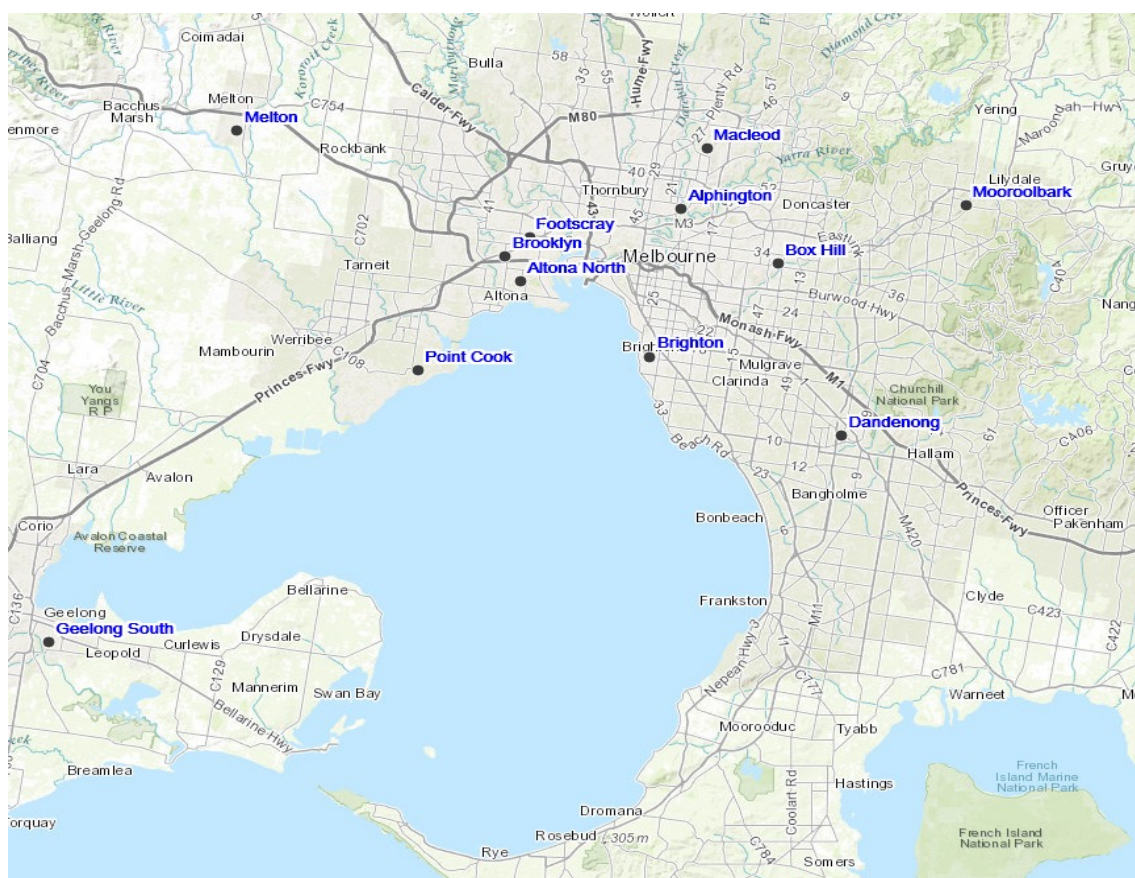
xiii Smut is specifically a fungal disease of grasses and cereals.



## Environment Protection Authority Victoria

The Environment Protection Authority (EPA) Victoria is an independent statutory authority whose role is to prevent and control air, land and water pollution, industrial noise and waste. EPA Victoria has a number of air quality monitoring stations across Victoria that measure air pollutants, including carbon monoxide, ozone, nitrogen dioxide, sulfur dioxide and fine particles as PM<sub>10</sub> or PM<sub>2.5</sub><sup>xiv</sup> (Figure 21).

**Figure 21: Air quality monitoring stations in greater Melbourne**



Source: Environment Protection Authority

xiv Particle Matter PM<sub>2.5</sub>, which is equal to or smaller than 2.5 micrometres in size and Particle Matter PM<sub>10</sub>, which is equal to or smaller than 10 micrometres. By definition PM<sub>10</sub> include PM<sub>2.5</sub>.

Air quality monitoring data is made available through the EPA AirWatch webpage and is incorporated into an annual report on Victoria's ambient air quality.

Hourly air quality measurements of the different air pollutants for 21 November 2016 between 5 and 7 pm are provided below as they were published on their website on that day<sup>xv</sup> (see Table 2 and Table 3).

The only measured air pollutant in Melbourne and Geelong that showed significant change from usual levels during the event and was found to exceed an air quality guideline/standard or markedly exceed an indicative hourly air quality guideline on 21 November 2016 was PM<sub>10</sub>.

**Table 2: EPA air quality hourly updates: 21 November 2016, 5–6 pm**

**EPA air quality hourly update: November 21, 2016 5.00 pm - 6.00 pm**

*Please note that current data may not be shown for some air quality monitoring stations. Measurements are made continuously at air monitoring stations, but there may be temporary technical issues with the collection and display of data.*

		Hour: <a href="#">current</a>   <a href="#">next</a>   <a href="#">previous</a>   <a href="#">choose...</a>							Show: <a href="#">data readings</a>   <a href="#">index values</a>	
Data readings									Air quality index	
Region	Station	Carbon Monoxide	Ozone	Nitrogen Dioxide	Sulfur Dioxide	Particles as PM2.5	Particles as PM10	Visibility Reduction	AQI	Summary
Units		ppm	ppb	ppb	ppb	ug/m3	ug/m3	none		
EAST	Alphington	0.2	36	6	0		15.5	0.37	36	GOOD
	Box Hill*					1.2*			5	VERY GOOD
	Brighton*					1.7*			7	VERY GOOD
	Dandenong*			6		4.0*	16.6	0.41	21	VERY GOOD
	Mooroolbark*		34			1.2*	23.1	0.46	34	GOOD
WEST	Altona North*			6	0	3.8*			15	VERY GOOD
	Brooklyn						191.5	0.65	239	VERY POOR
	Footscray	0.2	36	6		8.7	108.4		136	POOR
	Melton*		35			3.0*			35	GOOD
	Pt Cook*		38			2.2*		0.59	38	GOOD
NORTH	Macleod*					2.1*			8	VERY GOOD
GEELONG	Geelong Sth.	0.2	35	4	0	10.0	139.9	0.54	175	VERY POOR
LATROBE VALLEY	Morwell Sth.	0.3	38	4	1	10.2		0.40	41	GOOD
	Morwell East	0.1			3	11.2		0.45	45	GOOD
	Traralgon	0.1	33		0	9.4	33.3	0.45	42	GOOD
	Moe					11.5			46	GOOD
	Churchill					9.2			37	GOOD
REGIONAL VICTORIA	Wangaratta*					1.8*			7	VERY GOOD

xv. All levels in Melbourne and Geelong returned to either very good to good levels in the hour 7–8 pm.

**Table 3: EPA air quality hourly updates: 21 November 2016, 6–7 pm**

**EPA air quality hourly update: November 21, 2016 6.00 pm - 7.00 pm**

Please note that current data may not be shown for some air quality monitoring stations. Measurements are made continuously at air monitoring stations, but there may be temporary technical issues with the collection and display of data.

Hour: [current](#) | [next](#) | [previous](#) | [choose...](#) Show: [data readings](#) | [index values](#)

Data readings									Air quality index	
Region	Station	Carbon Monoxide	Ozone	Nitrogen Dioxide	Sulfur Dioxide	Particles as PM2.5	Particles as PM10	Visibility Reduction	AQI	Summary
	Units	ppm	ppb	ppb	ppb	ug/m3	ug/m3	none		
EAST	Alphington	0.2	25	9	0		137.6	0.59	172	VERY POOR
	Box Hill*					1.4*			6	VERY GOOD
	Brighton*					2.1*			8	VERY GOOD
	Dandenong*			5		4.3*	151.7	0.88	190	VERY POOR
	Mooroolbark*		24			1.4*	58.4	0.50	73	FAIR
WEST	Altona North*			12	0	3.9*			16	VERY GOOD
	Brooklyn						103.0	0.61	129	POOR
	Footscray	0.2	26	8		8.3	100.2		125	POOR
	Melton*		31			2.9*			31	VERY GOOD
	PT. Cook*		31			2.3*		0.58	31	VERY GOOD
NORTH	Macleod*					2.2*			9	VERY GOOD
GEELONG	Geelong Sth.	0.2	28	7	0	9.5	21.1	0.45	38	GOOD
LATROBE VALLEY	Morwell Sth.	0.3	39	4	1	9.8		0.45	39	GOOD
	Morwell East	0.1			4	11.3		0.52	45	GOOD
	Traralgon	0.1	33		0	9.8	23.0	0.49	39	GOOD
	Moe					11.3			45	GOOD
	Churchill					9.1			36	GOOD
REGIONAL VICTORIA	Wangaratta*					1.8*			7	VERY GOOD

The health-based air quality standard for PM<sub>10</sub> is based on a 24-hour period and is 50 µg/m<sup>3</sup>. This was not exceeded on 21 November at Alphington, Dandenong, Footscray or Mooroolbark but was exceeded at Geelong South (50.6 µg/m<sup>3</sup>) and Brooklyn (56 µg/m<sup>3</sup>).

The five-minute PM<sub>10</sub> averages of EPA Victoria data better demonstrate the onset and magnitude of the increase detected at each monitoring station as the wind changed with the approaching thunderstorm (Table 4).

**Table 4: PM<sub>10</sub> five-minute updates: 21 November 2016, 5–7.10 pm**

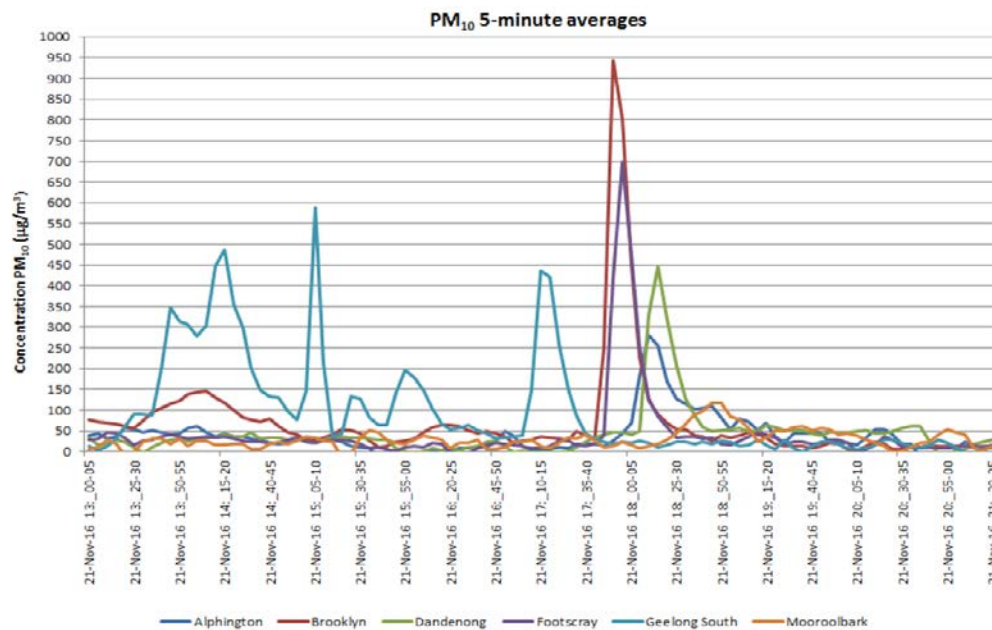
Date/time (DST)	Alphington	Brooklyn	Dandenong	Footscray	Geelong South	Mooroolbark
21-Nov-16 17:_00-05	14.4	24.8	-0.3	13.7	38.2	23.9
21-Nov-16 17:_05-10	4.2	29.2	-1.3	8.5	148.9	29.1
21-Nov-16 17:_10-15	1.8	36.0	-1.3	9.4	435.8	14.4
21-Nov-16 17:_15-20	6.5	34.6	-1.8	14.3	419.8	8.7
21-Nov-16 17:_20-25	11.0	29.9	-1.2	26.9	257.2	20.8
21-Nov-16 17:_25-30	8.8	28.1	1.8	24.8	150.1	34.4
21-Nov-16 17:_30-35	18.9	49.4	11.4	16.4	88.2	32.2
21-Nov-16 17:_35-40	19.3	38.3	24.5	13.5	44.3	42.0
21-Nov-16 17:_40-45	19.6	31.1	33.2	17.4	30.7	25.5
21-Nov-16 17:_45-50	12.3	250.5	41.3	39.9	23.5	9.9
21-Nov-16 17:_50-55	24.9	942.5	46.7	417.9	19.5	12.8
21-Nov-16 17:_55-00	44.5	803.2	45.5	698.6	22.6	23.5
21-Nov-16 18:_00-05	69.6	447.8	40.5	473.2	21.6	15.6
21-Nov-16 18:_05-10	182.3	227.0	49.7	253.9	26.3	8.6
21-Nov-16 18:_10-15	279.7	123.5	328.4	129.0	19.9	14.5
21-Nov-16 18:_15-20	254.8	88.8	446.9	84.0	11.7	17.2
21-Nov-16 18:_20-25	169.2	68.4	319.5	58.8	14.8	28.8
21-Nov-16 18:_25-30	127.3	53.5	208.4	33.2	23.4	43.5
21-Nov-16 18:_30-35	114.5	53.1	129.0	36.9	24.5	65.9
21-Nov-16 18:_35-40	103.4	39.4	86.4	35.2	18.0	89.4
21-Nov-16 18:_40-45	104.6	35.8	58.6	30.1	24.5	98.3
21-Nov-16 18:_45-50	110.6	27.0	48.5	32.8	18.0	117.5
21-Nov-16 18:_50-55	81.5	37.8	51.2	19.1	26.6	116.6
21-Nov-16 18:_55-00	53.2	34.6	53.6	16.3	23.7	84.3
21-Nov-16 19:_00-05	79.9	39.4	56.3	25.4	13.7	77.8
21-Nov-16 19:_05-10	72.9	46.9	49.4	36.7	15.0	57.5
21-Nov-16 19:_10-15	51.3	41.8	48.5	45.9	28.3	24.7

Note: Highlighted numbers demonstrate the onset and magnitude of the increase in PM<sub>10</sub> concentrations detected at each monitoring station as the wind changed with the approaching thunderstorm.

Higher PM<sub>10</sub> levels were measured earlier in the day at the Brooklyn and Geelong South sites when northerly winds prevailed before the thunderstorm arrived. The Brooklyn and Geelong South sites are regularly affected by local activities generating dust, which can result in increases in PM<sub>10</sub> levels.

The arrival of wind gusts from the thunderstorm outflow can be seen in the increases in particulate matter as it raises dust and other material. Soon after 5 pm the winds changed from northerly to west-southwesterly and triggered a cascading, transient increase in PM<sub>10</sub> across the monitoring network, initially at Geelong South; 40 minutes later at Brooklyn and then Footscray five minutes after that (highlighted in Table 4). Alphington rose one hour after Geelong South and soon after Dandenong and finally Mooroolbark (Figure 22).

**Figure 22: PM<sub>10</sub> five-minute averages measured during the afternoon and evening of 21 November 2016**



Unlike PM<sub>10</sub> levels, the PM<sub>2.5</sub> levels were not markedly elevated and were well below the indicative one-hour air quality guideline<sup>xvi</sup> used as a marker for poor air quality. This means the rise in PM<sub>10</sub> measured was primarily between 2.5 µm and 10 µm in size, commonly known as the coarse fraction of PM<sub>10</sub>. It is common to measure elevated coarse fraction of PM<sub>10</sub> during high wind events, which are referred to as raised dust events.

<sup>xvi</sup> The 'indicative one-hour air quality guideline' is a measure that has been derived from the national 24-hour air quality standard and is used to indicate poor air quality.

An analysis of the frequency and intensity of raised dust events in the Melbourne area for the 10 years between 2007 and 2016 found:

- Raised dust events occurred on average, nine days per year.
- Almost all raised dust events occurred between November and March.
- Years with fewer raised dust events correspond to wetter years.
- The raised dust event on 21 November 2016 was ranked 16th (in terms of the severity of peak hourly PM<sub>10</sub> concentration) out of the 90 raised dust events that were measured between 2007 and 2016.
- Of the 23 raised dust events recorded in spring between 2007 and 2016, 21 November 2016 was ranked as the fourth in terms of severity. (Note: The most severe raised dust event in spring was on 25 November 2015.)
- The number of raised dust events varied each year during the past decade, with the most (17 for each year) being recorded in 2008 and 2009.
- None matched previously identified epidemic thunderstorm asthma days.



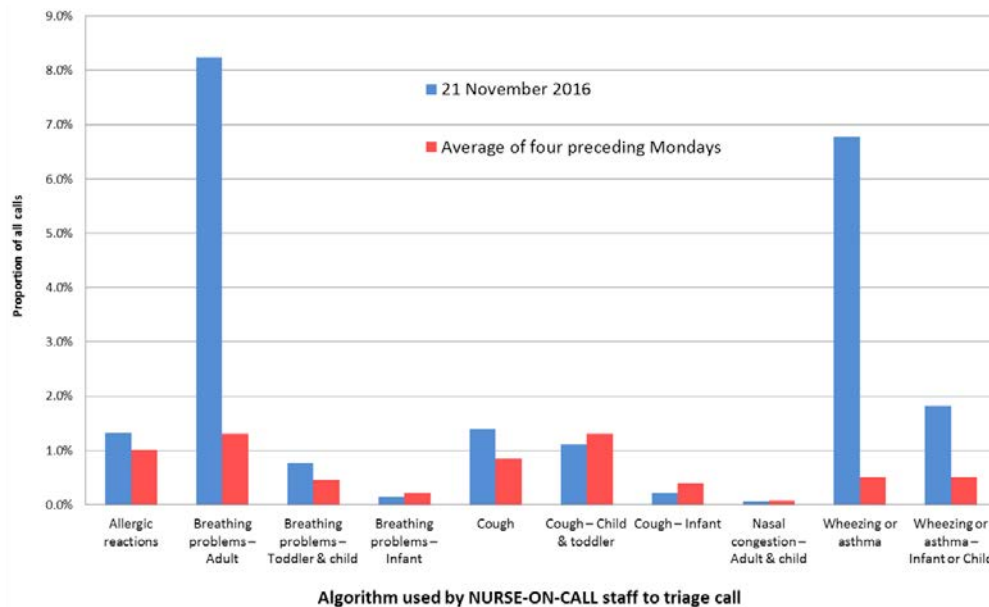
## Health impact

### NURSE-ON-CALL

The NURSE-ON-CALL (NOC) service provides Victorians with immediate, expert health advice from a registered nurse, 24-hours a day, seven days a week. Nurses triage incoming calls using clinical algorithms specific to the caller’s health concern or symptoms, which also direct the line of questions and the care management advice provided.

On Monday, 21 November 2016, NOC triaged 1,358 calls from the Victorian community. This is 420 (45 per cent) more calls than the average number of calls triaged by the service operator over the preceding four Mondays. A greater proportion of the calls triaged related to respiratory or allergy-related concerns (23 per cent) than would usually be expected. Typically, 6.6 per cent of calls relate to respiratory or allergy-related concerns. The majority of these calls were triaged as ‘Breathing Problems – Adult’ (118 calls, or 8.7 per cent of total calls answered) and ‘Wheezing or Asthma – Adult’ (97 calls, or 7.1 per cent of total calls answered) (Figure 23).

**Figure 23: NURSE-ON-CALL call types on Monday, 21 November 2016 compared with the preceding four Mondays (respiratory and allergy triage calls only)**

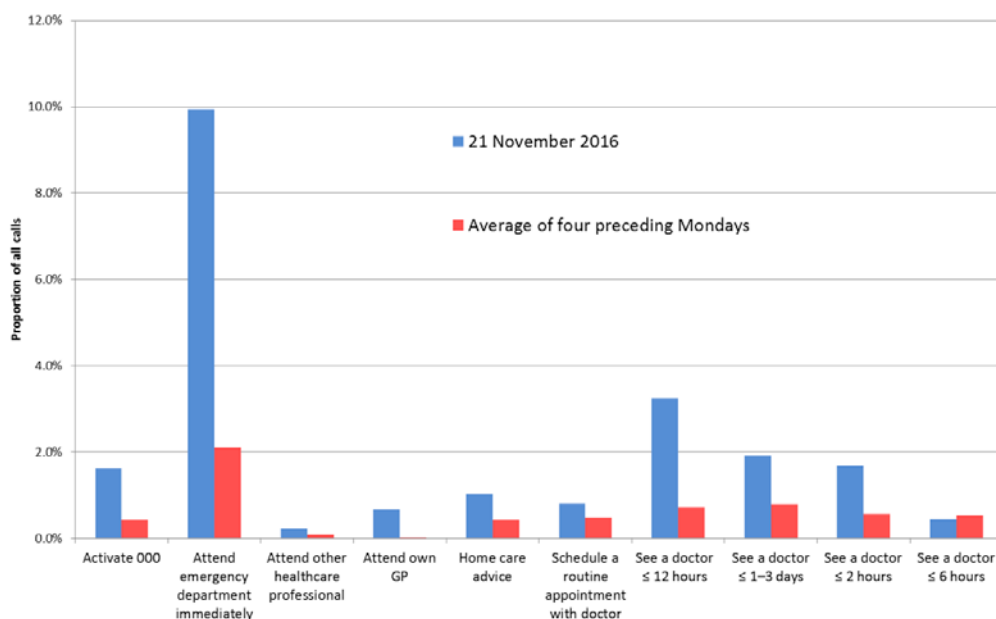


On Monday, 21 November 2016, a greater proportion of calls with respiratory and allergy concerns resulted in NOC calling an ambulance for that caller ('activate 000') (1.6 per cent vs 0.4 per cent) or advice being given to attend an emergency department immediately (9.9 per cent vs 2.1 per cent) relative to the average for the preceding four Mondays (Figure 24). This suggests that not only were there more calls involving respiratory and allergy symptoms but that these calls were more acute in nature than is usually experienced by NOC. Alternatively, more callers may have been experiencing asthma symptoms for the first time and needed urgent medical assessment.

The increased rate of ambulance triage dispositions ('activate 000') for this group of algorithms was largely associated with the use of the triage algorithms 'Allergic reaction' and 'Adult breathing problems'.

The increased rate of advice to attend an emergency department immediately was most heavily driven by the use of the triage algorithms 'Adult breathing problems', 'Asthma or wheezing' and 'Breathing problems (infant and child)'.

**Figure 24: Triage disposition of NURSE-ON-CALL calls on Monday, 21 November 2016 (respiratory and allergy triage calls only)**





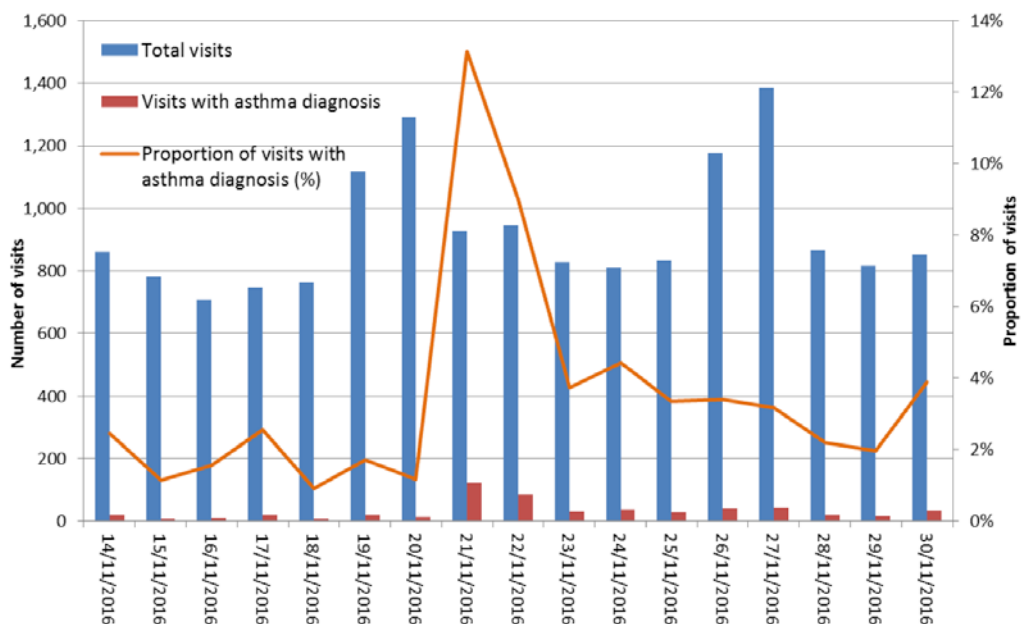
## National Home Doctor Service

The National Home Doctor Service (NHDS) provides after-hours medical care in the Melbourne, Geelong, Ballarat, Bendigo, Shepparton and Mornington Peninsula areas. Approximately 55 per cent of general practices in Melbourne direct their patients to NHDS outside of working hours to enable home visits and appropriate communication (diagnosis and management) to occur between the visiting doctor and the patient's usual general practitioner. NHDS also attend to patients from non-subscribing clinics.

The NHDS recorded 928 locum consultations on 21 November 2016 and 946 consultations on 22 November 2016, which is not significantly higher than the number of consultations usually seen on a Monday and Tuesday. However, analysis by NHDS of the number of calls for which there was no available doctor suggests the service was running at capacity and unable to accommodate more visits.

NHDS did, however, experience a large increase in the number of consultations with an asthma diagnosis (Figure 25). On 21 and 22 November, 122 (13.2 per cent) and 85 (9.0 per cent) visits, respectively, were for asthma. Typically, approximately 2 per cent of visits (on average 21 visits each night) on a Monday or Tuesday night are for asthma (Figure 25). The number of visits made for asthma remained elevated for the rest of the week.

**Figure 25: National Home Doctor Service total and asthma diagnosis visits for November 2016, Victoria**

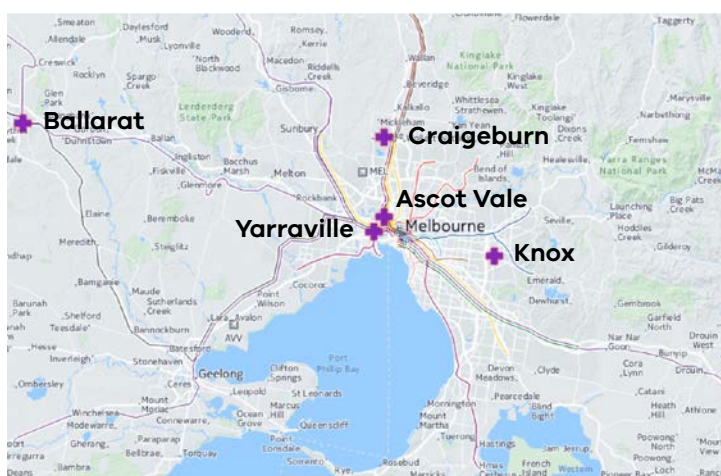


Source: National Home Doctor Service

## Supercare Pharmacies

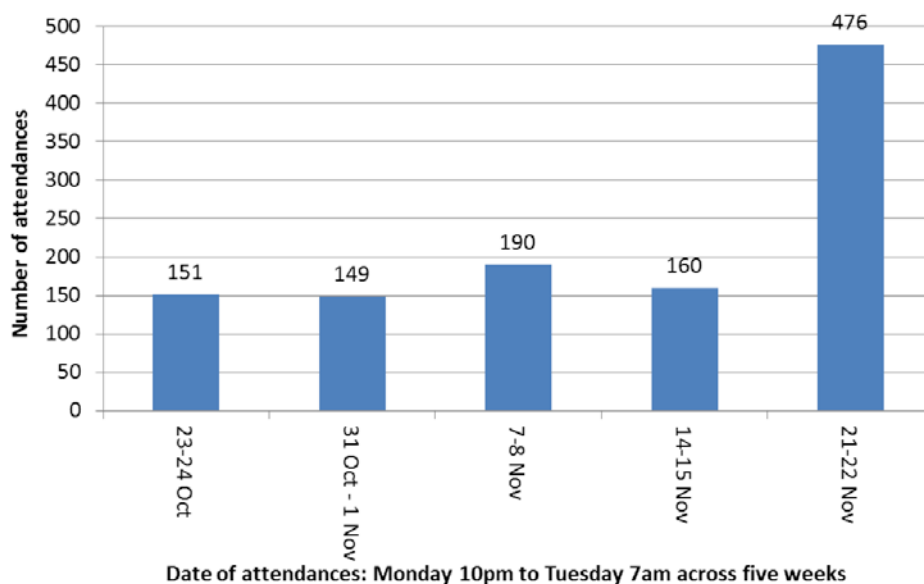
The Department of Health and Human Services has funded five pharmacies located in Craigieburn, Ballarat, Knox, Ascot Vale and Yarraville (see Figure 26) since July 2016 to operate as Supercare Pharmacies whereby they remain open 24 hours a day, seven days a week, with a nursing service available from 6 to 10 pm each day. The department collects de-identified pharmacy attendance data between the hours of 10 pm and 7 am on a weekly basis.

Figure 26: Supercare Pharmacy locations, Victoria, 2016



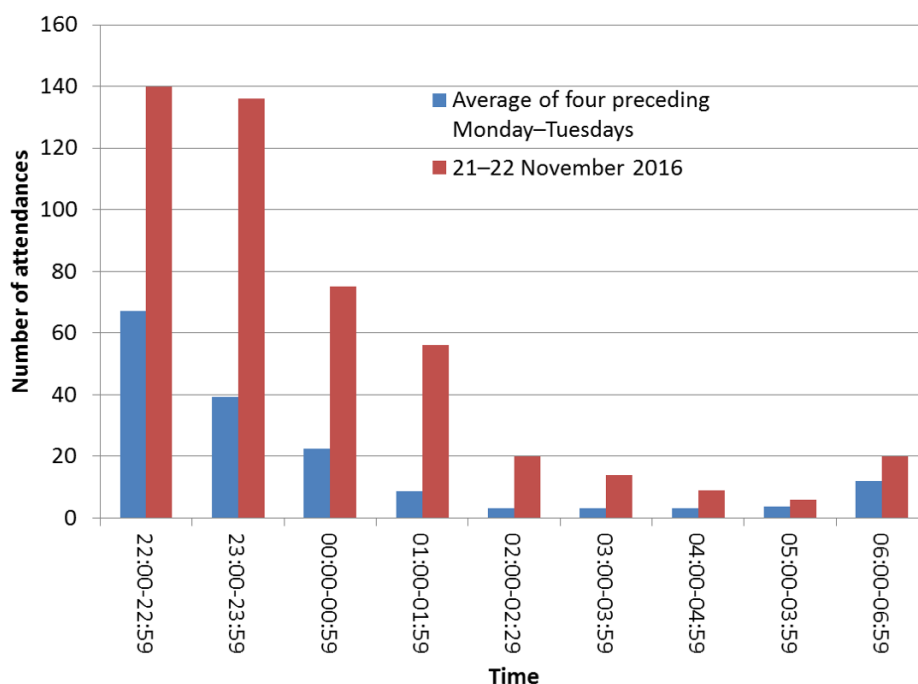
As with other health services, Supercare Pharmacies saw an increase in presentations during the thunderstorm asthma event. Between 10 pm on Monday 21 November and 7 am on Tuesday 22 November 2016, 476 people attended the five Supercare Pharmacies – a significant increase compared with attendance figures of the preceding four Monday evenings/Tuesday mornings (Figure 27).

Figure 27: Number of attendances at all Supercare Pharmacies on 21–22 November 2016 compared with the preceding four weeks, Monday 10 pm to Tuesday 7 am



Attendance by the hour (Figure 28) over the four Mondays preceding 21 November from 10 pm to 7 am the following Tuesday at all five Supercare Pharmacies demonstrates a significant increase throughout the evening of the thunderstorm asthma event and into the following morning.

**Figure 28: Pattern of attendance at Supercare Pharmacies by hour on 21–22 November 2016 compared with four preceding Mondays–Tuesdays**



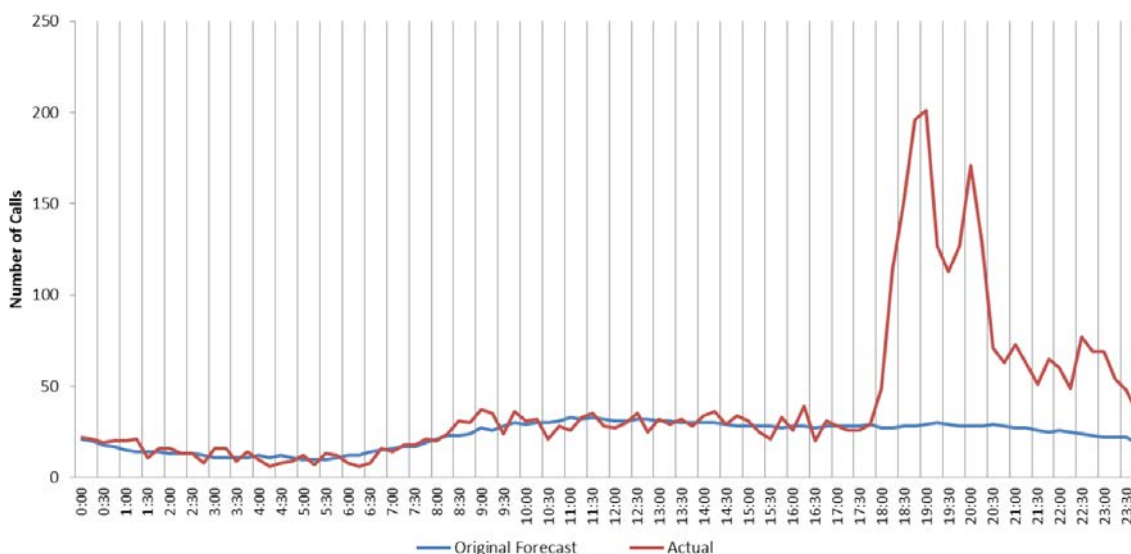
The nursing services at the Supercare Pharmacies also reported the administration of bronchodilators and high numbers of unwell patients requiring oxygen during the thunderstorm asthma event.

Individual pharmacies provided additional advice on bronchodilator and antihistamine use, in particular correct inhaler technique and the benefits of using a spacer. One pharmacy described an increase in sales of bronchodilators and preventers on Monday–Wednesday 21–23 November (573 sales) compared with Monday–Wednesday in the preceding week (65 sales).

## Ambulance Victoria

Ambulance Victoria reports that the first indication of increased demand came at 6.25 pm on 21 November 2016 when the regional duty manager of Ambulance Victoria’s Barwon South West region recorded that they were managing an increased caseload in and around Geelong.

**Figure 29: Emergency Services Telecommunications Authority call volumes for 21 November 2016 compared with forecast call volumes**



Source: Emergency Services Telecommunications Authority

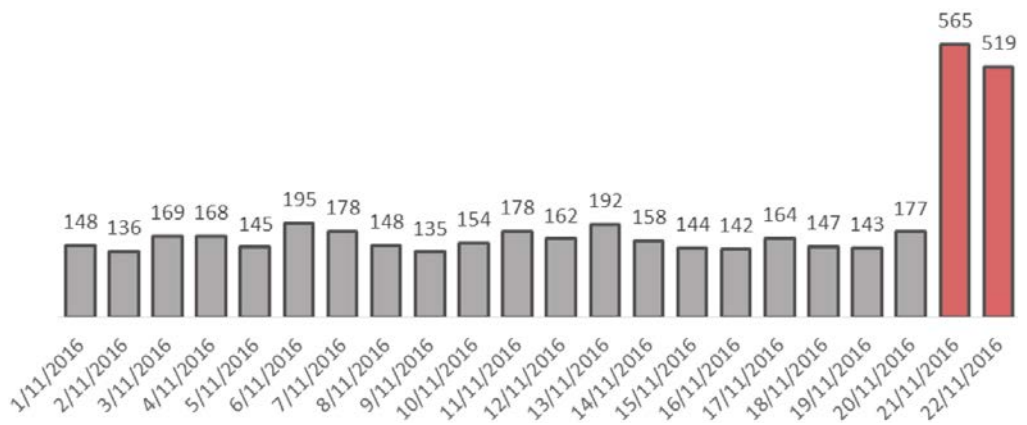
Overall on 21 November 2016, there were 1,626 more calls to the ESTA than were forecast (a 73 per cent increase).

As the number of calls increased, the resulting ambulance cases generated were unable to be resourced and the ‘pending list’ of un-resourced ambulance cases grew. The pending list peaked at approximately 8:00pm with over 150 cases in pending, and close to 100 of those being Code 1 cases.<sup>xvii</sup> The peak of demand lasted for three hours.

<sup>xvii</sup> Code 1 emergency ambulance cases are those that require most urgent attention and a ‘lights and sirens’ response.

The most marked increase in patients was among those reporting breathing problems. Figure 30 shows the significant increase in patients with a breathing problem on 21 and 22 November 2016 compared with the average for the preceding November period (159 cases), reflecting a 3.5- and 3.2-fold increase, respectively.

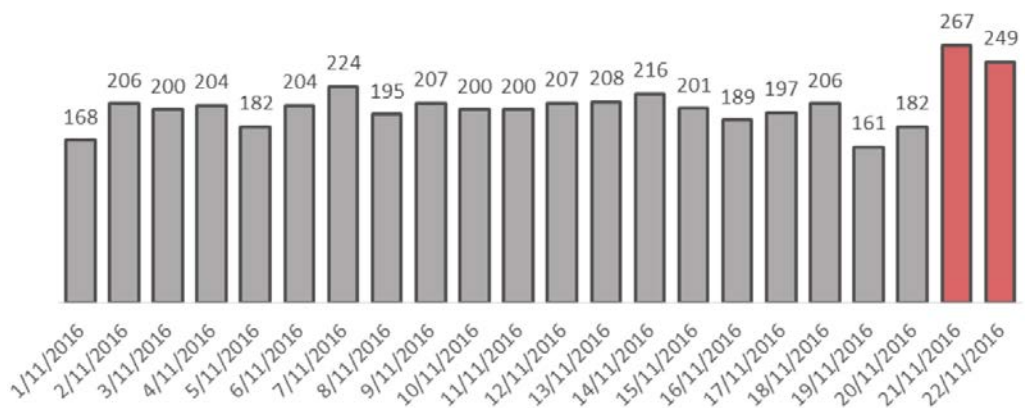
**Figure 30: Patients with breathing problems by day for November 2016**



Source: Ambulance Victoria

Patients with chest pain increased compared with the average for the preceding November period being 198 cases (Figure 31).

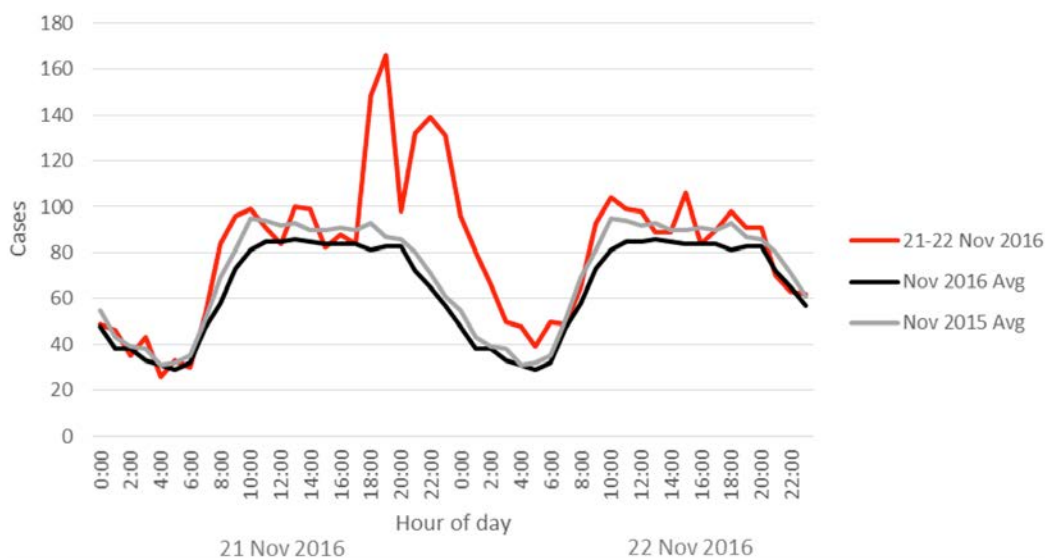
**Figure 31: Patients with chest pain by day for November 2016**



Source: Ambulance Victoria

The overall patient caseload experienced by Ambulance Victoria peaked at 7 pm. Ambulance Victoria reported the number of ambulance cases pending had decreased by 9.30 pm, at which stage it was deemed manageable; however, the total case load remained above average until 7 am on 22 November 2016 (Figure 32).

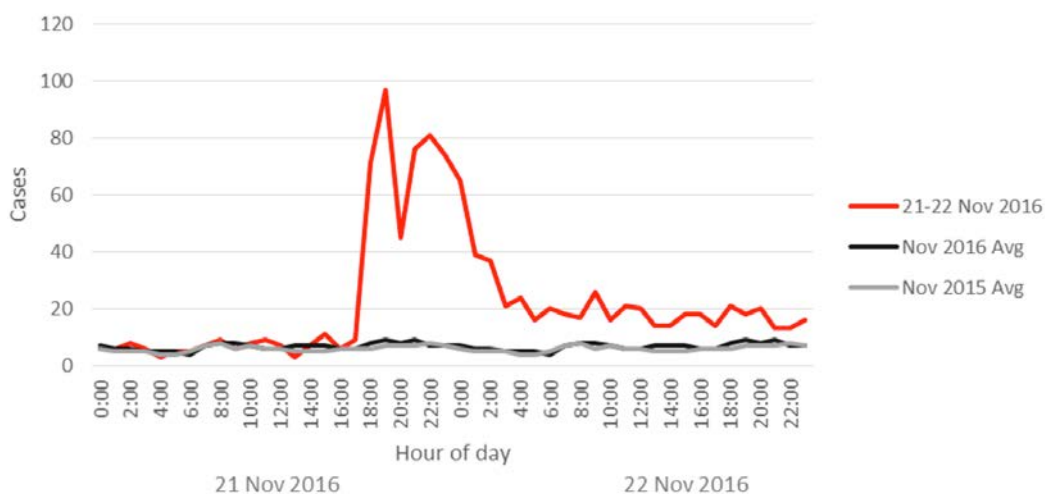
**Figure 32: Total number of Ambulance Victoria cases by hour for 21–22 November 2016**



Source: Ambulance Victoria

This sharp increase in overall patient numbers was driven by those reporting breathing problems (Figure 33). Examination of the problem type indicates a marked increase in breathing problems from 6 pm on 21 November. This caseload remained above average through 22 November 2016.

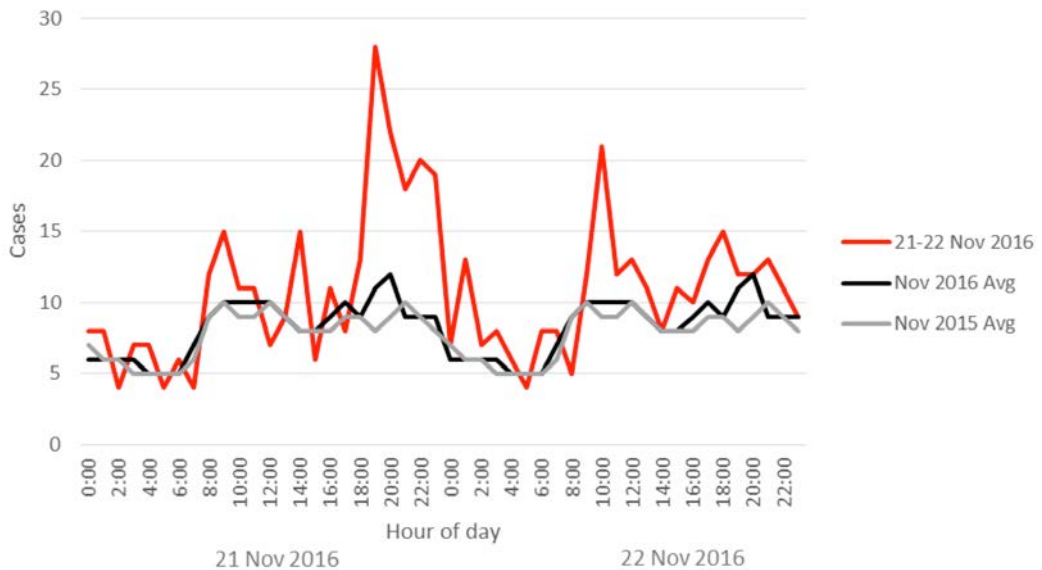
**Figure 33: Patients with breathing problems by hour for 21–22 November 2016**



Source: Ambulance Victoria

There was also a marked increase in chest pain cases from 6 pm (Figure 34), although these were fewer in number than breathing problems (Figure 33).

**Figure 34: Chest pain case load by hour for 21–22 November 2016**



Source: Ambulance Victoria

Between 6 pm and 11.59 pm on 21 November 2016, 814 cases were generated by Ambulance Victoria. The majority of these were Code 1 (643 cases). The majority of patients who called in this period were identified as having a 'breathing problem'.

Of all 814 cases, 17 suffered a cardiac arrest. Seven<sup>xviii</sup> of these cases were declared deceased at the scene, two patients were transported to hospital with mechanical CPR and eight patients were initially successfully resuscitated and transported to hospital with a pulse.

467 were transported to hospital, 77 as time-critical cases and 390 as non-time-critical.

In response to the unprecedented demand for ambulance services on 21 November 2016, Ambulance Victoria undertook a number of measures to respond. This included the recall of staff, deployment of additional paramedics and Mobile Intensive Care Ambulance units, recruitment of non-emergency contractors (St Johns Ambulance, Royal Flying Doctor Service resources, Health Select resources, Paramedic Services Victoria and Wilson Medic One resources), deployment of Field Emergency Medical Officers, other emergency services and community messaging via the Ambulance Victoria Twitter account.

xviii Note: The Ambulance Victoria interim report incorrectly states that eight cases were declared deceased at the scene. This will be corrected in their final report.

## Victorian public hospital emergency department presentations

The Victorian Emergency Minimum Dataset contains de-identified administrative and clinical information on presentations to public hospital emergency departments in Victoria.<sup>xix</sup>

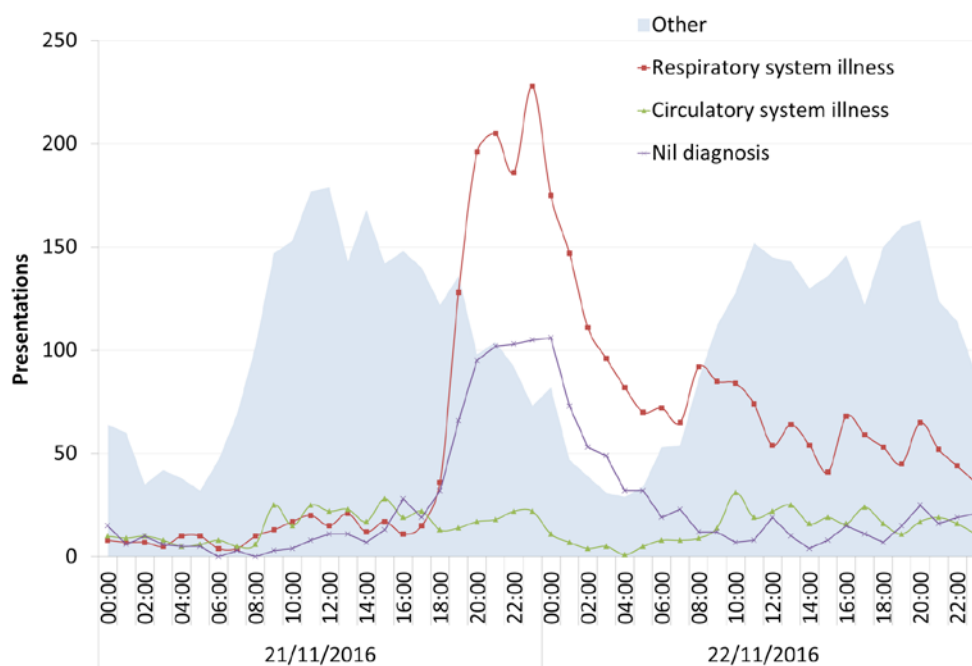
Total presentations and respiratory-related presentations were considered in this analysis. Respiratory-related presentations include those records containing an ICD-10-AM code that is included in the major diagnostic block of respiratory system illness.

This included people who were diagnosed in a Victorian public hospital emergency department with respiratory presentations such as asthma, wheeze, bronchiolitis and respiratory arrest.

The demand across public hospital emergency departments on 21 and 22 November 2016 was unprecedented and extraordinary. The focus was on providing urgent clinical care to the large influx of patients. Many hospitals reported patients being coded as 'nil diagnosis' after receiving treatment for asthma symptoms but leaving the emergency department in good condition prior to all aspects of the usual paperwork being completed.

Presentations to hospital emergency departments are coded and grouped into major diagnostic blocks, representing related conditions. All major diagnostic blocks were within normal variance on the 21 and 22 November, with the exception of the respiratory block and cases coded 'nil diagnosis'. Both respiratory and 'nil diagnosis' presentations were found to follow a very similar pattern, with a rapid rise around 6 pm on Monday 21 November, peaking at around midnight and then declining rapidly through the morning hours (Figure 35).

**Figure 35: Presentations to public hospital emergency departments by hour, 21–22 November 2016 (Melbourne and Geelong hospitals)**



<sup>xix</sup> Hospitals may resubmit data to the VEMD if an error is identified after the original monthly submission, meaning that the data in this analysis is technically considered provisional until late 2017. This is possible but was not expected at the time of preparing this report.



It appears likely that the transient, rapid and unusual increase in 'nil diagnosis' that mirrored the increase in respiratory system presentations were one in the same but simply not coded as such.

For this reason, patients coded 'nil diagnosis' over this specific period were included in the analysis of epidemic thunderstorm asthma presentations along with respiratory system presentations. This was felt to most accurately capture the complete patient group who were affected and then presented to emergency departments. For brevity, in the executive summary this group of respiratory and 'nil diagnosis' presentations is referred to as 'respiratory-related presentations'.

To determine the period of highest impact and the relative scale of the impact, presentations to hospital emergency departments over three different timeframes were examined: the two days of 21 and 22 November 2016, 30 hours from 6 pm on 21 November to 11.59 pm on 22 November 2016, and 21–30 November 2016. For comparison, the average number of presentations in the preceding three years (over the corresponding time period) was considered. Given the potential for emergency department presentations to vary by day of the week (for example, weekday to weekend), for the two-day and 30-hour averages the exact date of 21 and 22 November was not used to calculate the relevant three-year average because this includes weekend days. Instead, the closest Monday and Tuesday to 21 and 22 November in the preceding three years was used.<sup>xx</sup>

### **Total presentations**

The epidemic thunderstorm asthma event of 21 November resulted in record total presentations at public hospital emergency departments. Across Victoria, total statewide public hospital emergency department presentations for 21 and 22 November 2016 were 12,723, which is 3,867 (44 per cent) more than the average of the closest Monday and Tuesday in the preceding three years.

Almost all these extra presentations (3,643 of the 3,867 statewide cases, 94 per cent) involved hospitals in the greater Melbourne and Geelong region. Table 5 shows that 2,520 (97 per cent) of the 2,608 excess respiratory and 940 (95 per cent) of the 990 excess 'nil diagnosis' presentations, occurred in the Melbourne and Geelong region. This suggests that the increase in emergency department presentations was predominantly limited to the greater Melbourne and Geelong region.

xx Comparisons could be made in a number of ways including using a three-year average or the number of presentations in the preceding week – Monday 14 and Tuesday 15 November 2016. In the preceding week, there were 9,306 total presentations to public hospital emergency departments across the state compared with the three-year average of 8,856. Using the preceding week's comparison results in a calculation of 3,417 excess presentations on 21 and 22 November rather than the 3,867 calculated when the three-year average is used. Melbourne and Geelong public hospital emergency departments received 6,639 total presentations on the preceding Monday and Tuesday compared with a three-year average of 6,266. Using the preceding week's comparison results in a calculation of 3,270 excess presentations rather than 3,643 calculated when the three-year average is used.

**Table 5: Victorian public hospital emergency department presentations, 21–22 November 2016**

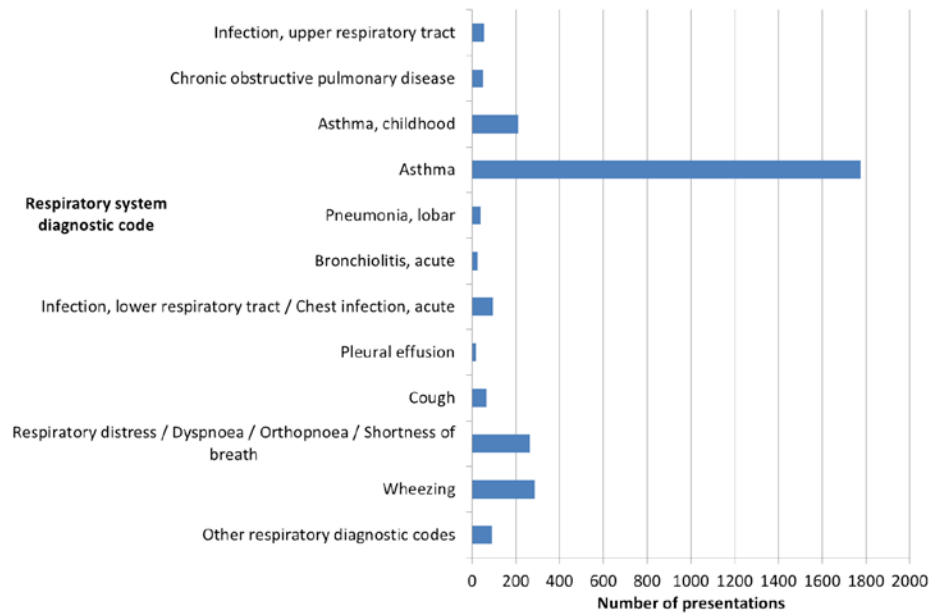
	Number of presentations	Three-year average	Excess cases (per cent increase on three-year average)
<b>Total presentations (including respiratory and 'nil diagnosis')</b>			
Melbourne and Geelong	9,909	6,266	3,643 (58%)
Other hospitals	2,814	2,590	224 (9%)
<b>Total</b>	<b>12,723</b>	<b>8,856</b>	<b>3,867 (44%)</b>
<b>Respiratory presentations</b>			
Melbourne and Geelong	2,973	453	2,520 (556%)
Other hospitals	239	151	88 (58%)
<b>Total</b>	<b>3,212</b>	<b>604</b>	<b>2,608 (432%)</b>
<b>'Nil diagnosis' presentations</b>			
Melbourne and Geelong	1,253	313	940 (300%)
Other hospitals	175	125	50 (40%)
<b>Total</b>	<b>1,428</b>	<b>438</b>	<b>990 (226%)</b>
<b>All other presentations (excluding respiratory and 'nil diagnosis')</b>			
Melbourne and Geelong	5,683	5,500	183 (3%)
Other hospitals	2,400	2,314	86 (4%)
<b>Total</b>	<b>8,083</b>	<b>7,814</b>	<b>269 (3%)</b>

Across 21 and 22 November the excess number of presentations to Victorian public hospital emergency departments was 3,867 (44 per cent increase above the three-yearly average of 8,856).

Over these two days the excess number of respiratory and 'nil diagnosis' presentations to Melbourne and Geelong public hospital emergency departments was 3,460 (452 per cent increase above three-yearly average of 766).

The most common respiratory presentation codes reported by Melbourne or Geelong public hospital emergency departments on these dates were 'asthma' or 'asthma, childhood' (67 per cent) (Figure 36). A number of patients were also coded as 'wheezing' (10 per cent) and 'respiratory distress/dyspnoea/orthopnoea/ shortness of breath' (9 per cent).

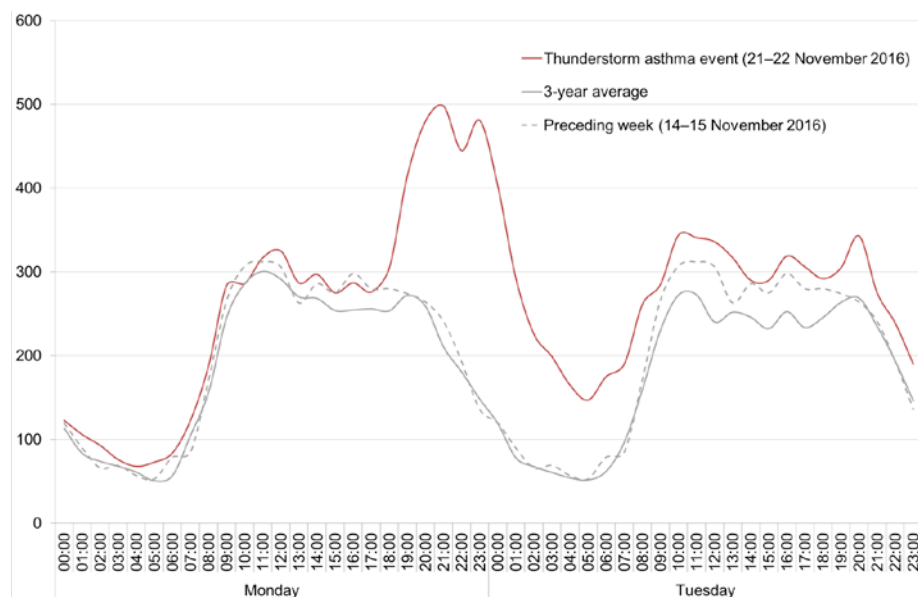
**Figure 36: Diagnostic codes for respiratory system presentations to Melbourne and Geelong public hospital emergency departments on 21–22 November 2016**



### Time of presentations

The increase in Victorian total emergency department presentations occurred suddenly from 6 pm on 21 November (Figure 37). Presentations per hour peaked at 9 pm, with 498 presentations between 9 pm and 10 pm and, while decreasing in the early hours of 22 November, remained well above the three-year average for the remainder of the day.

**Figure 37: Victorian total presentations at all public hospital emergency departments, 21–22 November 2016**



### Age and gender distribution of respiratory presentations or 'nil diagnosis'

Of the 4,226 respiratory and 'nil diagnosis' presentations made to Melbourne and Geelong public hospital emergency departments on 21 and 22 November, 1,832 (43.4 per cent) were presentations made by women and 2,394 (56.6 per cent) by men (Table 6). Among both men and women, the highest number of respiratory and 'nil diagnosis' presentations was observed in patients aged 15–44 years, particularly among those aged 25–34 years, with 888 presentations (21 per cent of all respiratory and 'nil diagnosis' presentations) (Table 6).

**Table 6: Age distribution of respiratory system and 'nil diagnosis' presentations to Melbourne and Geelong public hospital emergency departments, 21–22 November 2016**

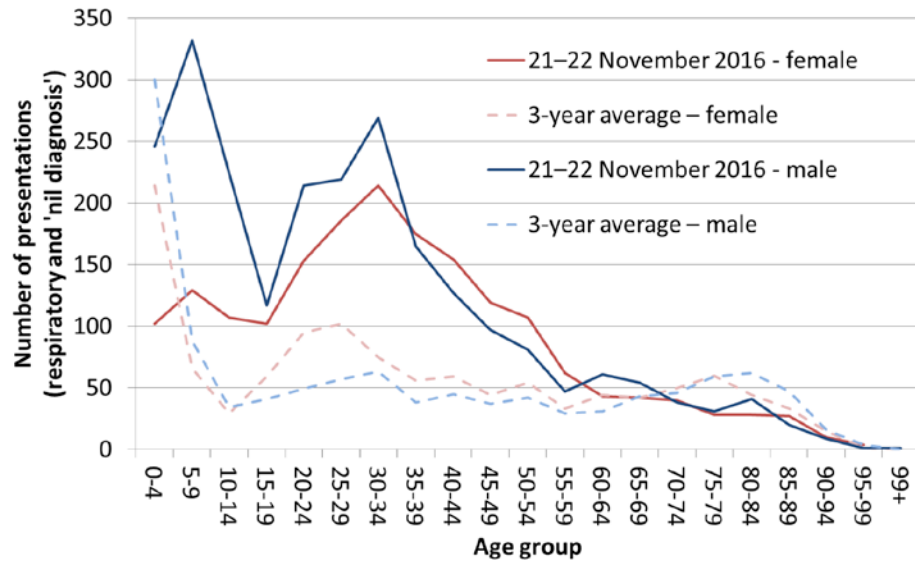
Age group (years)	Female (%)	Male (%)	Total (%)
0–4	102 (5.6)	246 (10.3)	348 (8.2)
5–9	129 (7.0)	332 (13.9)	461 (10.9)
10–14	107 (5.8)	224 (9.4)	331 (7.8)
15–24	255 (13.9)	331 (13.8)	586 (13.9)
25–34	400 (21.8)	488 (20.4)	888 (21.0)
35–44	329 (18.0)	292 (12.2)	621 (14.7)
45–54	226 (12.3)	178 (7.4)	404 (9.6)
55–64	105 (5.7)	108 (4.5)	213 (5.0)
65–74	82 (4.5)	92 (3.8)	174 (4.1)
75+	97 (5.3)	103 (4.3)	200 (4.7)
Total	1,832	2,394	4,226

Asthma prevalence data indicates that in children under 14 years of age, boys are more likely to be diagnosed with asthma than girls. Typically this is reflected in more boys than girls aged 0–14 presenting to hospital emergency departments<sup>13</sup> (for example, see three-year average data in Figure 38).

While more young boys than girls were also seen on 21 and 22 November 2016, this higher proportion of males than females persisted through to the 40–44 year age group (Figure 38). This contrasts with usual asthma presentation patterns that show greater numbers of women than men presenting from the age of 14. Among those aged over 40, a greater number of presentations were made by women (664 (52.2 per cent)) (Figure 38).

Overall on 21 and 22 November, 332 (7.9 per cent) of all respiratory system and 'nil diagnosis' presentations were made by boys aged between five and nine. A second peak in presentations was seen in men aged 30–34 (269 presentations; 6.4 per cent) and women aged 30–34 (214; 5.1 per cent) (Figure 38).

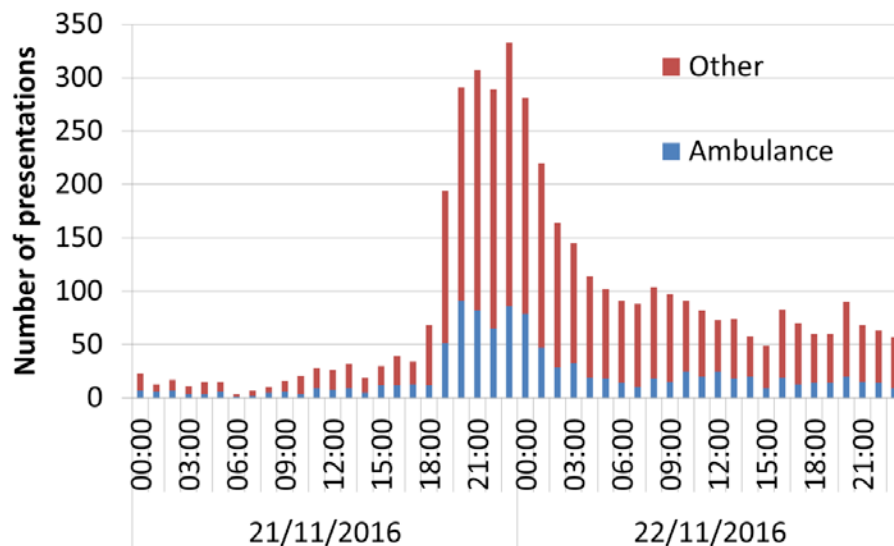
**Figure 38: Respiratory system and 'nil diagnosis' presentations to Melbourne and Geelong public hospital emergency departments, by age and sex for 21–22 November 2016 compared with three-year average**



**Mode of arrival to the emergency department for patients with respiratory system or 'nil diagnosis' presentations**

Typically, 24 per cent of patients presenting to public emergency departments do so by ambulance. While the volume of ambulance arrivals to emergency departments on 21 and 22 November 2016 was significantly increased, they comprised 25 per cent of total arrivals (Figure 39), with a proportional increase in patients who self-presented.

**Figure 39: Mode of arrival of respiratory system and 'nil diagnosis' presentations to Melbourne and Geelong public hospital emergency departments by hour, 21–22 November 2016**



### Severity of cases

Examining the triage category of these patients provides a measure of the severity of their condition. Triage is a process for immediately assessing patients who present seeking emergency care and is used to prioritise or classify patients according to illness or injury severity and their need for medical and nursing care (Table 7). In Australia, triage is predominantly a nursing assessment that begins when the patient presents to an emergency department.

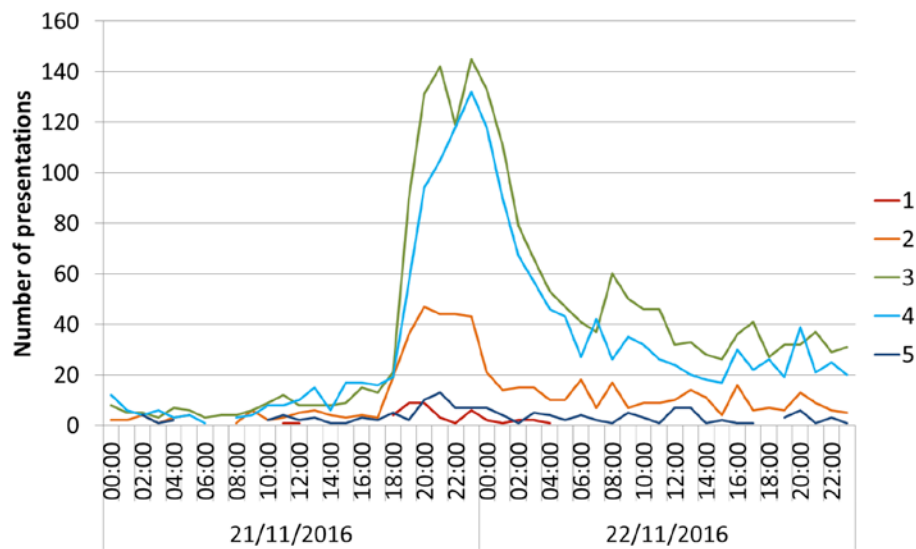
**Table 7: Australasian Triage Scale categories**

Australasian Triage Scale category	Response	Description
1	Immediate	Immediately life-threatening
2	Assessment and treatment within 10 minutes	Imminently life-threatening or important time-critical treatment or severe pain
3	Assessment and treatment within 30 minutes	Potentially life-threatening or situational urgency, or humane practice mandates the relief of severe discomfort or distress within 30 minutes
4	Assessment and treatment within 60 minutes	Potentially life-serious, or situational urgency, or significant complexity or severity, or humane practice mandates the relief of severe discomfort or distress within 60 minutes
5	Assessment and treatment within 120 minutes	Less urgent, or clinical-administrative problems

Source: Australasian College for Emergency Medicine 2000<sup>18</sup>

Eighty-three per cent of patients who presented with a respiratory system problem or who were coded as 'nil diagnosis' on 21 and 22 November 2016 were assigned a triage category of 3 (46 per cent) or 4 (37 per cent). There was also a significant increase in category 2 cases on 21 and 22 November (Figure 40).

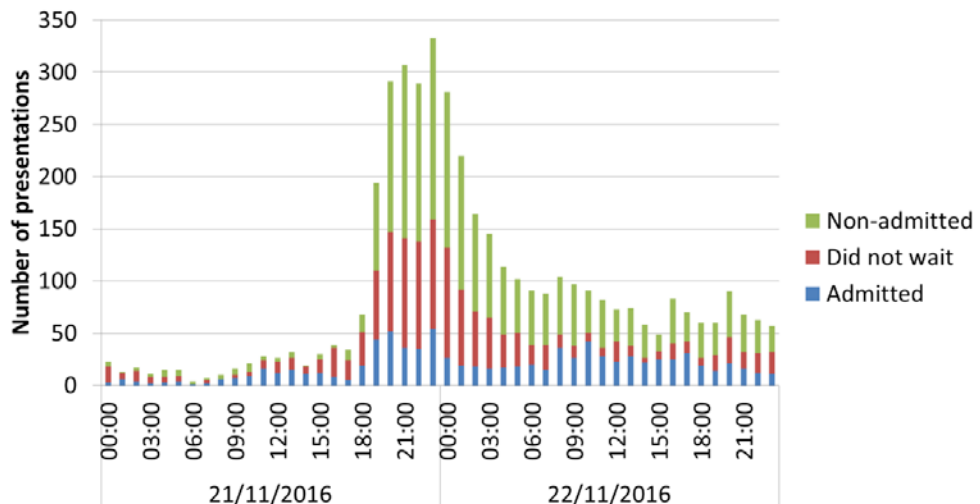
**Figure 40: Triage category for respiratory system and 'nil diagnosis' presentations to Melbourne and Geelong public hospital emergency departments, 21–22 November 2016**



**Patient departures from emergency departments**

Of the 4,226 respiratory or 'nil diagnosis' presentations to Melbourne and Geelong public hospital emergency departments on 21 and 22 November, 21 per cent were admitted, 49 per cent were not admitted and 30 per cent were coded as 'did not wait' (Figure 41).

**Figure 41: Departure status of respiratory system and 'nil diagnosis' presentations to Melbourne and Geelong public hospital emergency departments, 21–22 November 2016**



An admission is a process whereby a hospital accepts responsibility for a patient's care and/or treatment. Admission follows a clinical assessment based on specified criteria, that a patient requires same-day or overnight care or treatment. When a patient is transferred from an emergency department to a ward (including short stay units), the admission time is the time the patient physically departed from the emergency department rather than the time at which it was decided to transfer the patient.

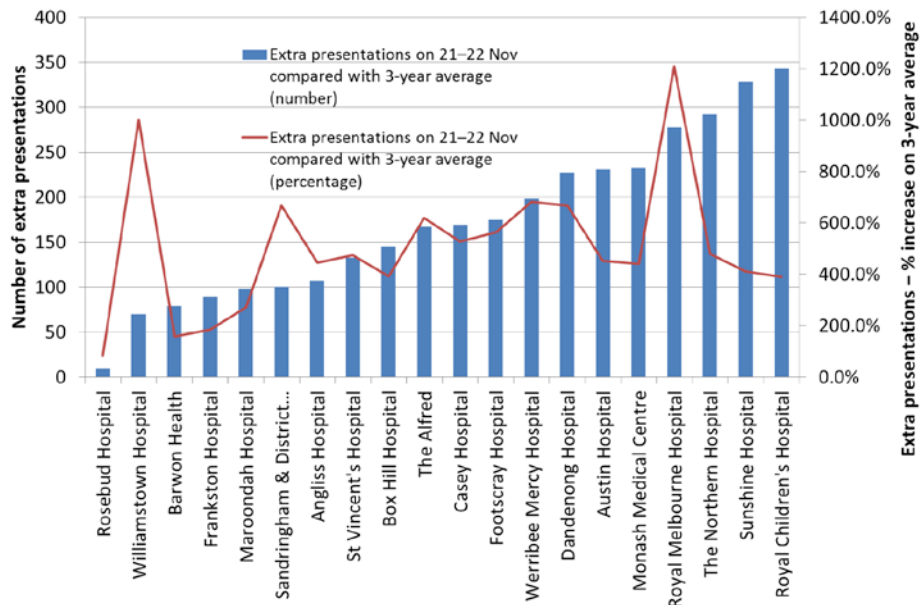
A diagnosis code must be entered for all presentations to emergency departments unless the patient did not wait for treatment. This is the same group of patients who were coded as presenting with 'nil diagnosis' and whom it was believed were patients who received treatment for asthma but left prior to all relevant paperwork being completed due to the significant demand on emergency department resources and the focus on providing urgent care to patients. However, it should be noted that there is limited information about this cohort, and some patients may have presented for different conditions and/or due to the high demand, elected not to wait.

#### **Individual hospital emergency department presentations**

The impact of the surge in emergency department presentations was felt by hospitals throughout metropolitan Melbourne and the Geelong region. The largest numbers of extra respiratory and 'nil diagnosis' patients compared with the average number of respiratory and 'nil diagnosis' presentations on the closest Monday and Tuesday to 21 and 22 November of the preceding three years were seen at the Royal Children's Hospital (343 extra cases), Sunshine Hospital (329 extra cases) and The Northern Hospital (292 extra cases) (Figure 42). However, the largest proportional increase in patient load was at Williamstown and Royal Melbourne hospitals, which saw a 10-fold (70 vs seven) and 12-fold (278 vs 23) increase in respiratory and 'nil diagnosis' cases, respectively. A further four Melbourne public hospital emergency departments (Sandringham and District Memorial Hospital, Dandenong Hospital, Mercy Werribee Hospital and The Alfred) had a greater than six-fold increase in respiratory and 'nil diagnosis' cases (Figure 42).

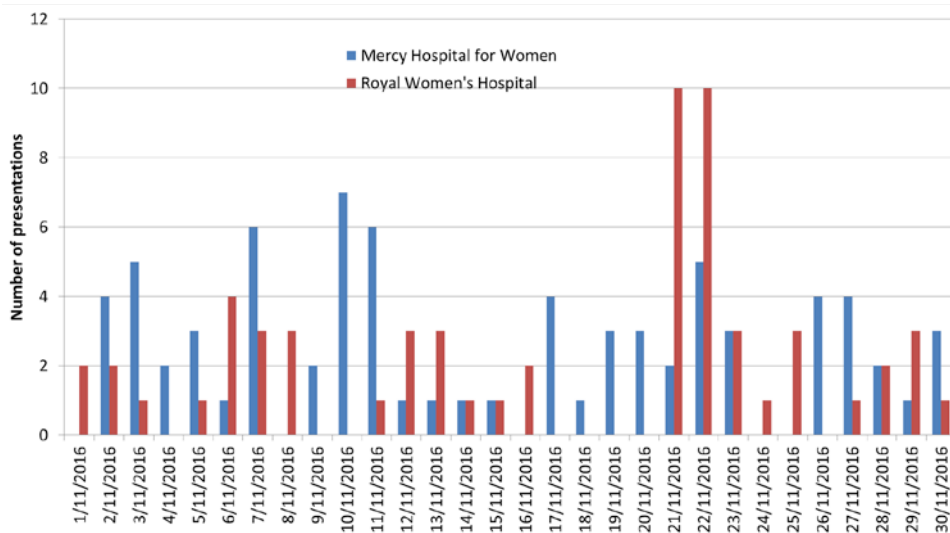


**Figure 42: Extra respiratory system and 'nil diagnosis' presentations, by Melbourne and Geelong hospital compared with the three-year average, 21–22 November 2016**



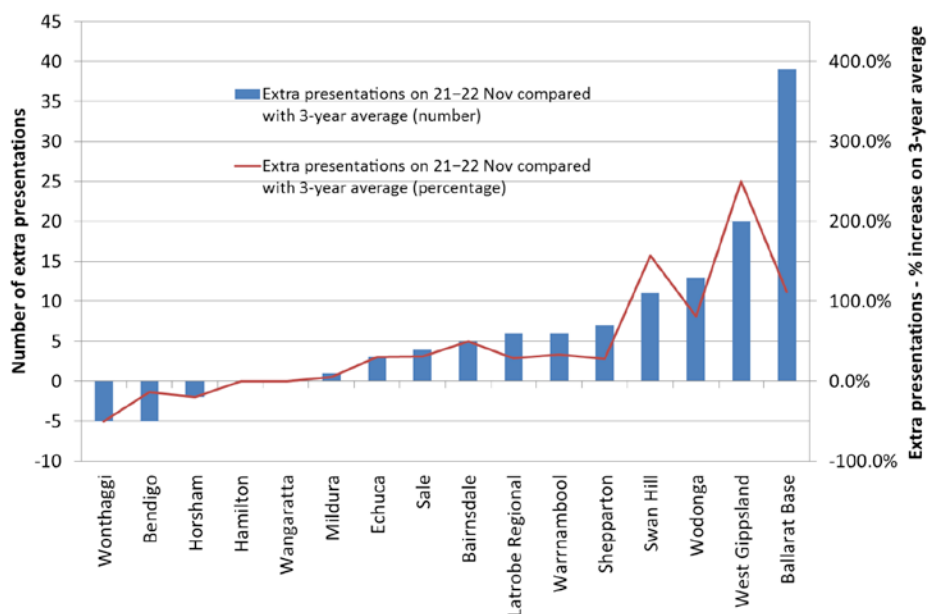
There was also an increase in respiratory and 'nil diagnosis' presentations to the emergency departments of the two specialised women's hospitals in Melbourne: the Mercy Hospital for Women and the Royal Women's Hospital. While the number of respiratory and 'nil diagnosis' presentations to these hospitals is highly variable over the month (Figure 43), the Royal Women's Hospital saw a five-fold (17 vs three) increase and the Mercy Hospital for Women a 2.5-fold (five vs two) increase on their average number of respiratory and 'nil diagnosis' presentations.

**Figure 43: Daily respiratory system and 'nil diagnosis' presentations to specialised women's hospitals in Melbourne, November 2016**



In addition to presentations in the Melbourne and Geelong area, increases in presentations were seen in a small number of regional hospitals. Seventy-four patients presented to Ballarat Base Hospital on 21 and 22 November, 39 (111 per cent) more than expected based on the three-year average for the Monday and Tuesday closest to 21 and 22 November. West Gippsland Hospital in Warragul also saw an increase in respiratory and 'nil diagnosis' presentations, with 28 presentations – 20 (250 per cent) more than the three-year average of eight presentations (Figure 44).

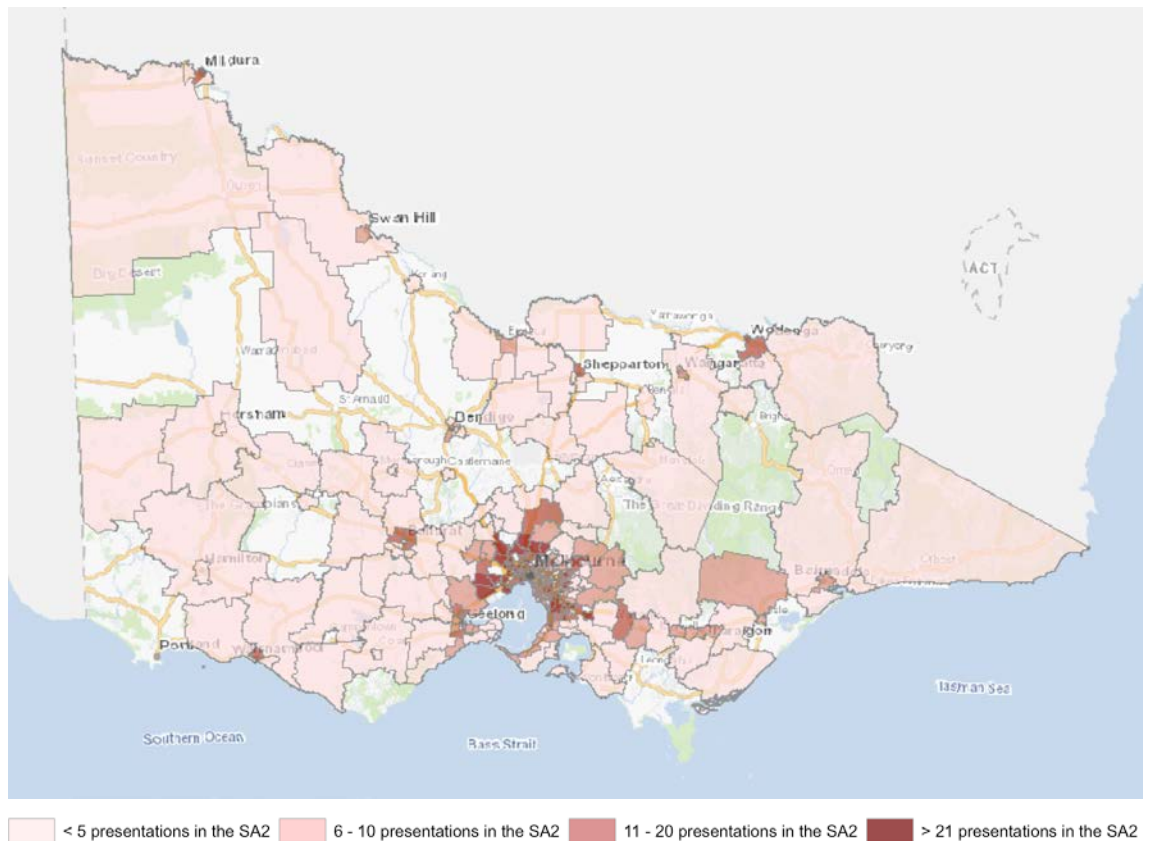
**Figure 44: Extra respiratory system and 'nil diagnosis' presentations by regional hospital compared with three-year average, 21–22 November 2016**



### Postcode of those who presented to emergency departments

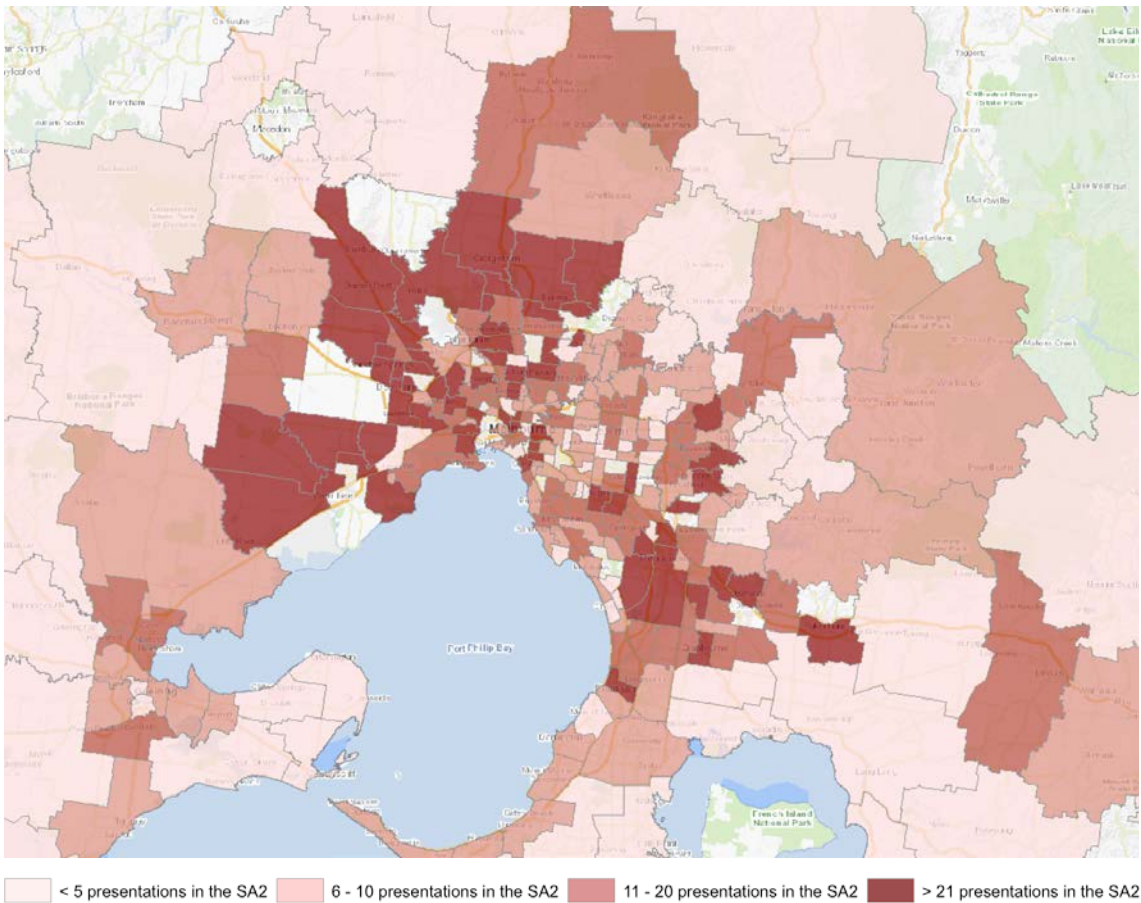
The geographic distribution of those who presented to a public hospital emergency department was broad with some predominance to the north and west of Melbourne. The maps shown in Figure 45 and Figure 46 reflect the crude number of respiratory and 'nil diagnosis' presentations by home postcode of the patient.

**Figure 45: Home postcode of patients with a respiratory system or 'nil diagnosis' presentation to all Victorian public hospitals on 21 and 22 November 2016 (map showing all of Victoria)**



Note: Statistical area level 2 (SA2) is one of the spatial units defined under the Australian Statistical Geography Standard. This standard is a hierarchical geographical classification, defined by the Australian Bureau of Statistics, which enables the production of statistics which are comparable and can be spatially integrated.

**Figure 46: Home postcode of patients with a respiratory system or 'nil diagnosis' presentation to all Victorian public hospitals on 21 and 22 November 2016 (map showing greater Melbourne and Geelong region)**



The analysis of presentation data was also undertaken using a 30 hour period from 6 pm on 21 November 2016 and for the period from 21 November to 30 November 2016. These results are summarised below.

### **Total presentations**

- Between 6 pm on Monday 21 November and 11.59 pm on Tuesday 22 November 2016 the excess number of presentations to Victorian public hospital emergency departments was 3,496 (a 62 per cent increase above the three-year average of 5,659), resulting in a total of 9,155 presentations.
- Throughout 21 and 22 November the excess number of presentations to Victorian public hospital emergency departments was 3,867 (a 44 per cent increase above the three-year average of 8,856), resulting in 12,723 presentations.
- From 21 to 30 November 2016 the excess number of presentations to Victorian public hospital emergency departments was 8,056 (a 19 per cent increase above the three-year average of 43,075), resulting in 51,131 presentations.

### **Respiratory and 'nil diagnosis' presentations**

- Between 6 pm on Monday 21 November and 11.59 pm on Tuesday 22 November 2016 the excess number of respiratory and 'nil diagnosis' presentations to Melbourne and Geelong public hospital emergency departments was 3,365 (a 672 per cent increase above the three-year average of 501), resulting in a total of 3,866 presentations.
- Throughout 21 and 22 November the excess number of respiratory and 'nil diagnosis' presentations to Melbourne and Geelong public hospital emergency departments was 3,460 (a 452 per cent increase above the three-year average of 766), resulting in 4,226 presentations.
- From 21 to 30 November 2016 the excess number of respiratory and 'nil diagnosis' presentations to Melbourne and Geelong public hospital emergency departments was 4,944 (a 135 per cent increase above the three-year average of 3,663), resulting in 8,607 presentations.

## Victorian private hospital emergency department presentations

A small number of private hospitals in Melbourne and Geelong offer a private emergency department service. The Department of Health and Human Services does not routinely collect this data; however, following the epidemic thunderstorm asthma event, private hospitals (Knox Private, Peninsula Private, Cabrini, Epworth Richmond and Epworth Waurn Ponds, Valley Private, John Fawkner Private and St John of God Geelong hospitals) were contacted and asked to provide de-identified emergency department data from 21 and 22 November 2016.

In all, 927 patients were seen in these private hospital emergency departments in the Melbourne and Geelong areas over 21 to 22 November 2016. On average, on a Monday and Tuesday in November over the previous three years, 696 patients were seen. This indicates that private hospital emergency department experienced 231 (33 per cent) more presentations than would be expected based on the three-year average.

## Admissions to Victorian public and private hospitals

The Victorian Admitted Episodes Dataset is a comprehensive dataset of the causes, effects and nature of illness, and the use of health services in Victoria. All Victorian public and private hospitals, including rehabilitation centres, extended care facilities and day procedure centres, report a minimum set of data for each admitted patient episode to the department.

All asthma-related hospital admissions in November 2016 in Victoria were considered in the analysis.

To determine the period of highest impact and the relative scale of the impact, admissions over four different timeframes were examined: all of November; the two days of 21 and 22 November 2016; 30 hours from 6 pm from 21 November to 11.59 pm on 22 November 2016; and 21–30 November 2016. For comparison, the average number of admissions in the preceding three years (over the corresponding time period) was considered. Given the potential for admissions to vary by day of the week (for example, weekday to weekend), for the two-day and 30-hour averages the exact date of 21 and 22 November was not used to calculate the relevant three-year average because this includes weekend days. Instead, the closest Monday and Tuesday to 21 and 22 November in each of the three years was used.

## Total number of asthma-related admissions and asthma-related intensive care unit admissions

In November 2016 there were 2,915 asthma-related admissions to Victorian hospitals. This represents 1,068 (59 per cent) more admissions than expected based on average total November admission rates for the preceding three years<sup>xxi</sup> (Table 8). This consisted of a 77 per cent increase in asthma admissions for Melbourne and Geelong public hospitals and a smaller 14 per cent increase for the remainder of Victorian hospitals.

xxi It should be noted that the number of admissions grows every year, with the growth in the second quarter of 2016–17 from the second quarter of 2015–16 being 6.7 per cent.

An intensive care unit (ICU) is a specially staffed and equipped unit in a hospital that provides care for patients with life-threatening conditions. There was a marked increase in ICU admissions related to asthma in November 2016, with 122 asthma-related admissions requiring a period of ICU care. This was 39 (47 per cent) more admissions than would be expected based on the three-year average (Table 8).

**Table 8: Victorian hospital asthma-related admissions, November 2016**

	Number of admissions	Three-year November average	Excess cases (% increase on three-year average)
<b>All asthma-related admissions (including intensive care unit admissions)</b>			
Melbourne and Geelong	2,275	1,284	991 (77%)
Other hospitals	640	563	77 (14%)
<b>Total</b>	<b>2,915</b>	<b>1,847</b>	<b>1,068 (59%)</b>
<b>Asthma-related intensive care unit admissions</b>			
Melbourne and Geelong	94	55	39 (71%)
Other hospitals	28	28	0 (0%)
<b>Total</b>	<b>122</b>	<b>83</b>	<b>39 (47%)</b>

### Time of admissions

The most admissions for asthma occurred on 21 and 22 November 2016, with 653 asthma-related admissions statewide (Figure 47). This is 520 (391 per cent) more admissions than expected based on the three-year average.

These asthma admissions were compressed into the time period after the thunderstorm arrived. The increase in admissions is better described by the 601 admissions in the 30 hours after 6 pm on 21 November 2016 compared with the 77 that were expected – a 681 per cent increase.

Significantly, in this 30-hour period there were 524 asthma-related admissions to public hospitals in Melbourne and Geelong, representing a 992 per cent increase on the expected 48 admissions.

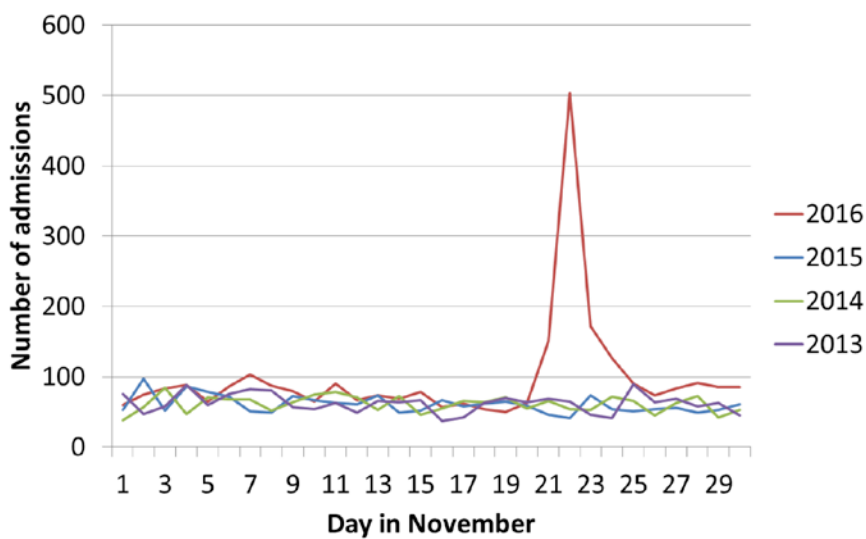
Admission numbers remained markedly elevated on 23 and 24 November and, while decreasing on 25 November, remained above average across the state for the rest of the month.

From 21 November to the end of November there were 1,460 admissions for asthma in Victoria compared with a three-year average of 579. This is an excess of 881 cases (60 per cent of which occurred in the first 30 hours after the onset of the event from 6 pm on 21 November).



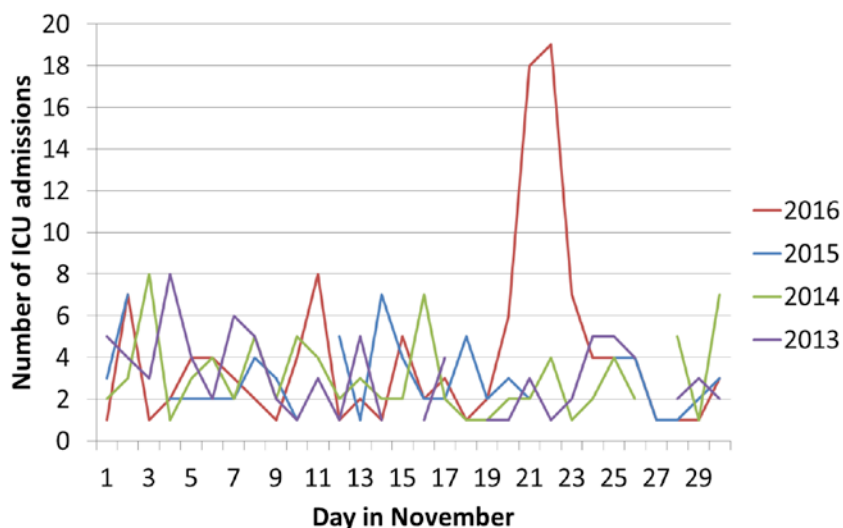
However, analysis of the daily admission rate prior to 21 November 2016 indicates the rate of admissions was already 186 more than expected for the month, based on the preceding three-year average. This suggests Victorian hospitals were already experiencing higher numbers of asthma admissions in November prior to the epidemic thunderstorm asthma event occurring (Figure 47).

**Figure 47: Total asthma-related hospital admissions for November from 2013 to 2016 (all Victorian hospitals)**



ICU admissions are a subset of total admissions and given the small number of admissions requiring this level of care, show much more variability over the month. Despite this, a marked increase in asthma-related admissions to ICU is seen on 21 and 22 November 2016. Thirty seven asthma-related admissions from 21 and 22 November required a period in ICU. In preceding years, the highest number of asthma-related admissions requiring ICU on a single day was eight. Admissions on both the 21 and 22 November 2016 were more than double this.

**Figure 48: Total asthma-related ICU admissions for November from 2013 to 2016 (all Victorian hospitals)**





There were 39 excess asthma-related ICU admissions in Victoria in the month of November 2016 (Table 8). Between 6 pm on 21 November and 11.59 pm on 22 November 2016, there were 30 excess asthma-related ICU admissions, a 3,000 per cent increase on the three-year average for this period of one admissions.

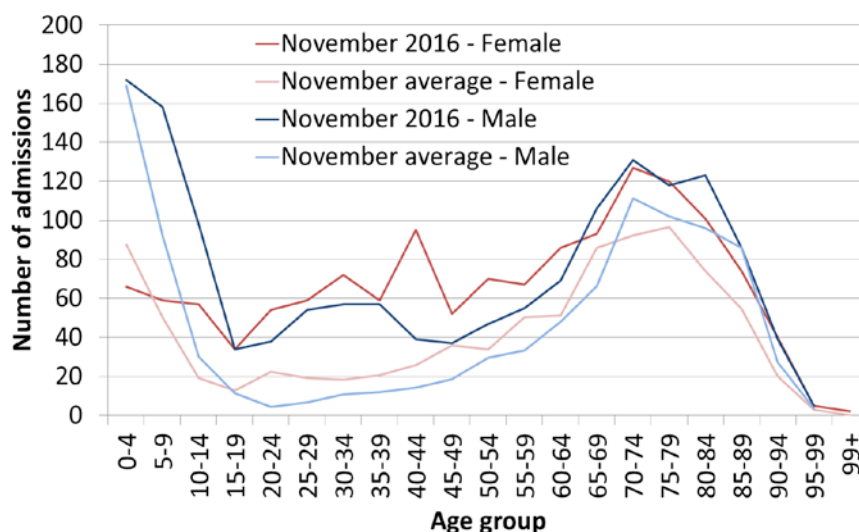
Between 6 pm on 21 November and 11.59 pm on 22 November 2016, hospitals with the highest numbers of asthma-related ICU admissions included Barwon Hospital,<sup>xxii</sup> Dandenong Hospital, Footscray Hospital, the Royal Melbourne Hospital and Sunshine Hospital, which all received three asthma-related ICU admissions. The Austin Hospital, Monash Medical Centre and the Royal Children’s Hospital each had two ICU admissions in this period. One asthma-related ICU admission occurred in this period outside the Melbourne and Geelong region. This was at Goulburn Valley Health in Shepparton.

#### Age and gender distribution of asthma-related admissions

The highest number of hospital admissions for asthma was observed in children from birth to four years, particularly boys who had 172 admissions (5.9 per cent of all admissions) (Figure 49). In November 2016, a greater number of boys aged 0–14 years were admitted to hospital for asthma than girls and, among those aged 15–65 years, females had more asthma admissions than males, after which males remained slightly higher. This gender difference is consistent with other studies of asthma admissions and prevalence patterns.<sup>13,19</sup>

There were some unique characteristics in the age and gender distribution of asthma-related hospital admissions in November 2016 compared with previous years. Asthma admission rates are typically highest among those aged under five years and over 65 years. In November 2016 a greater proportion of asthma admissions were among patients aged 10–60 years (Figure 49). This difference between 2016 and previous years was particularly marked in the 20–44 year age group, who comprised 20 per cent of all asthma admissions in November 2016 compared with 8 per cent in a typical year.

**Figure 49: Age and gender distribution of asthma-related hospital admissions for November 2016 compared with the November average from 2013 to 2015**



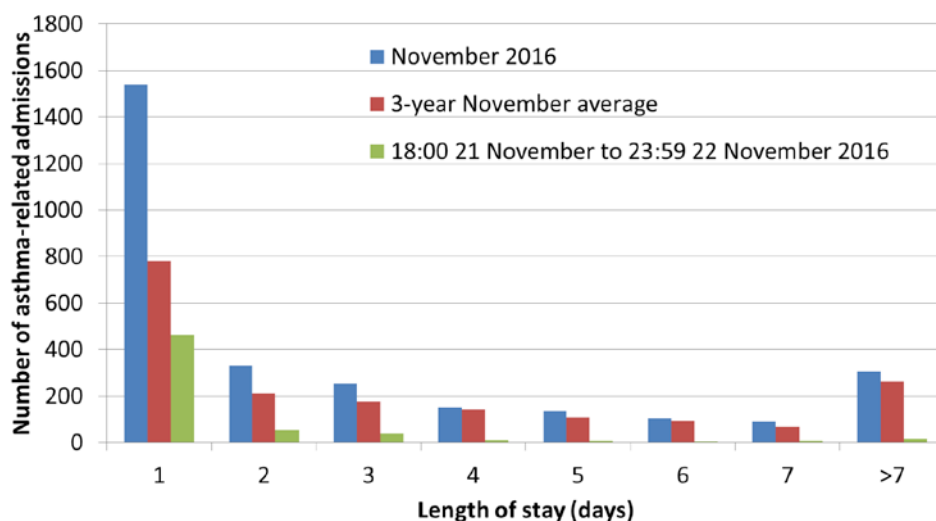
xxii Barwon Hospital (University Hospital Geelong) is the largest public hospital in Geelong.

### Length of stay

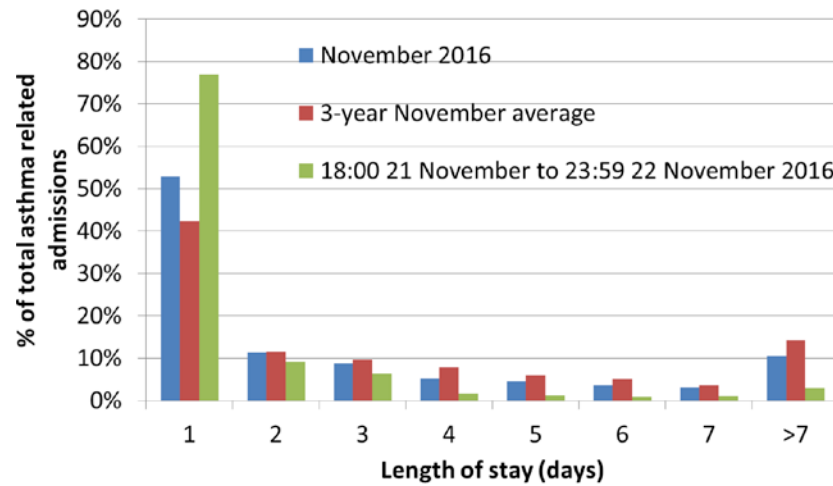
The duration of an admission in hospital or 'length of stay' reflects the severity and complexity of the patient's condition. Figure 50 and Figure 51 show that more than half of the asthma-related admissions in November 2016 were one day in length. Such short durations of stay suggest patients were quickly stabilised and ready for discharge. This may also reflect a healthier or younger patient cohort affected by the epidemic thunderstorm asthma event with fewer comorbidities than are usually found in patients admitted for asthma. However, while most asthma-related admissions appear to have been relatively straightforward and short in November 2016 compared with previous years, the ICU data presented above does suggest that a significant proportion of cases were severely unwell.

Seventy-seven per cent of patients admitted with asthma between 6 pm on 21 November and 11.59 pm on 22 November 2016 had admissions lasting one day or less (Figure 51). On average in November over the past three years, only 42 per cent of asthma-related admissions are of this short duration.

**Figure 50: Length of stay of asthma-related hospital admissions in November, 2013 to 2016 (all Victorian hospitals)**



**Figure 51: Length of stay of asthma-related hospital admissions in November as a percentage of all asthma admissions, 2013 to 2016 (all Victorian hospitals)**



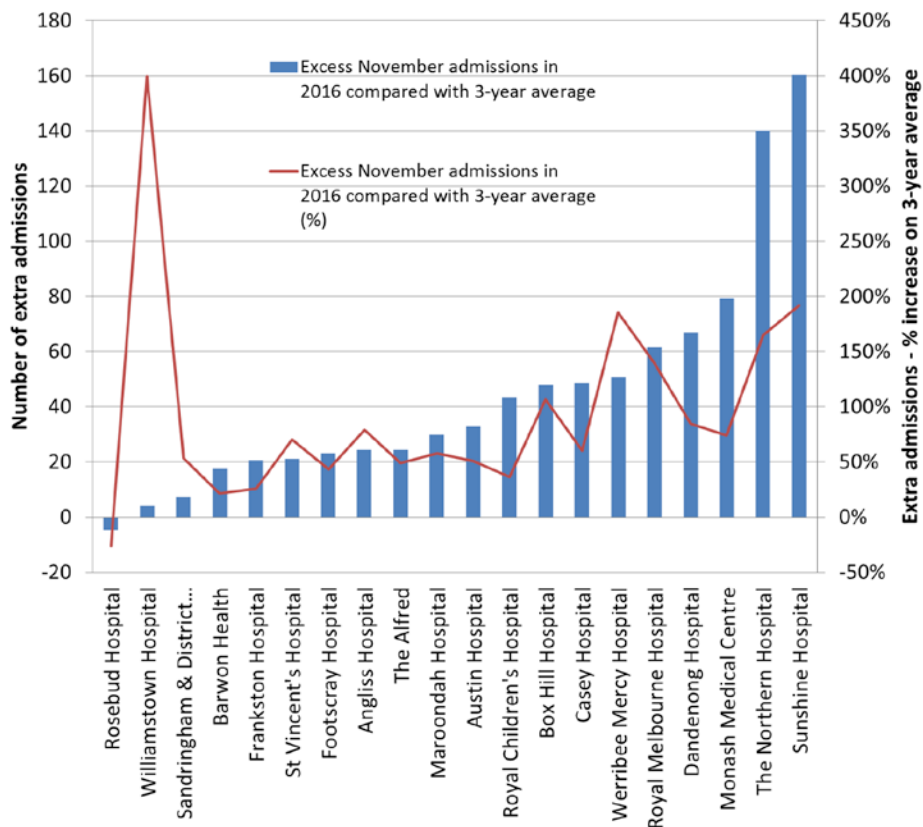
A short stay observation unit is a ward providing targeted care for patients requiring brief hospitalisation and who are expected to be discharged as soon as their clinical conditions are resolved.

On 21 and 22 November 2016 there were 315 asthma-related admissions to short stay units across Victoria compared with a three-year average of 20.

### Admissions by hospital

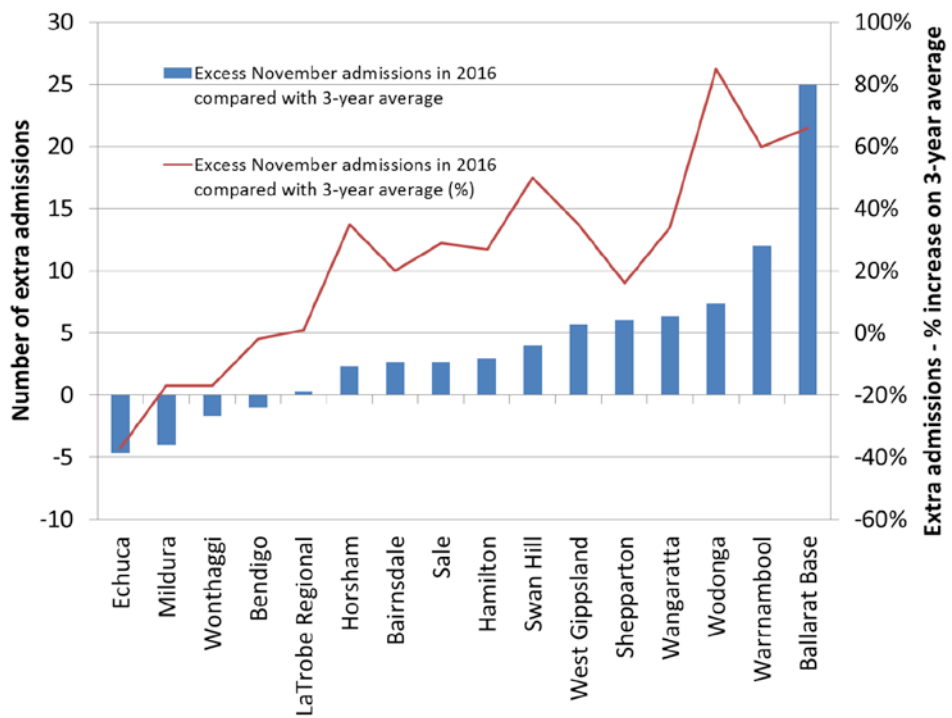
Hospitals throughout the Melbourne and Geelong region saw an increase in asthma-related admissions in November 2016 compared with their respective three-year November averages (Figure 52). The Sunshine Hospital and the Northern Hospital experienced particularly large increases in asthma admissions – 160 (292 per cent) and 140 (265 per cent) extra admissions, respectively. Williamstown Hospital only had five asthma-related admissions for the month; however, this is a four-fold increase on the hospital’s usual asthma admission rate.

**Figure 52: Extra asthma-related admissions by hospital in November 2016 compared with the average of November admissions for 2013 to 2015 (Melbourne and Geelong hospitals)**



Outside the Melbourne and Geelong region, a number of hospitals experienced increases in asthma-related admissions compared with their respective three-year November averages (Figure 53). Ballarat Base Hospital had 25 more asthma admissions for the month compared with the 38 expected, a 67 per cent increase. Thirty-two asthma-related admissions were made to Warrnambool in November 2016, 12 (60 per cent) more than expected. Similarly, although Wodonga only had 16 asthma-related admissions in total in November 2016, this represents an 85 per cent increase on the expected number of admissions.

**Figure 53: Extra asthma-related admissions by regional hospital for November 2016 compared with average November admissions for 2013 to 2015**



The analysis of admission data was also undertaken using a 30 hour period from 6 pm on 21 November 2016 and for the period from 21 November to 30 November 2016. These results are summarised below.

### **Asthma-related admissions**

- Between 6 pm on Monday 21 November and 11.59 pm on Tuesday 22 November 2016 the excess number of asthma-related admissions to Victorian hospitals was 524 (a 681 per cent increase; 601 total admissions).
- Throughout 21 and 22 November the excess number of asthma-related admissions to Victorian hospitals was 520 (a 391 per cent increase; 653 total admissions).
- From 21 to 30 November 2016 the excess number of asthma-related admissions to Victorian hospitals was 881 (a 152 per cent increase; 1,460 presentations).

### **Asthma-related ICU admissions**

- Between 6 pm on Monday 21 November and 11.59 pm on Tuesday 22 November 2016 the excess number of asthma-related ICU admissions to Victorian hospitals was 30 (a 3,000 per cent increase; 31 admissions).
- Throughout 21 and 22 November the excess number of asthma-related ICU admissions to Victorian hospitals was 34 (a 1,133 per cent increase; 37 presentations).
- From 21 to 30 November 2016 the excess number of asthma-related ICU admissions to Victorian hospitals was 37 (a 148 per cent increase; 62 presentations).

## Deaths

In December 2016 the State Coroner announced a coronial investigation into the circumstances of each death possibly related to the epidemic thunderstorm asthma event. The investigation aims to identify common themes and focus on opportunities to address systemic issues that could prevent similar deaths in the future. This investigation was still underway at the time this report was being prepared.

This analysis considers the total number of deaths and deaths for which asthma is currently considered as the cause, with an acknowledgement that the coronial investigation is still underway. It considers data from the Coroners Court of Victoria and the Victorian Registry of Deaths, Births and Marriages.

### Coroners Court of Victoria

Certain deaths are required by law to be reported to the Coroners Court of Victoria. This includes deaths: that are unexpected or appear to have resulted directly or indirectly from accident or injury; where the identity of the person is not known; or where a medical practitioner has been unable to provide a death certificate.

De-identified data was requested from the Coroners Court for all reported deaths from 21 to 30 November 2016 and from 21 to 30 November 2013, 2014 and 2015 for comparison. This included demographic details of the deceased and their cause of death. Deaths are reported to the Coroners Court from all around Victoria, and the data may include records for people who normally live in other states or territories, or overseas.

There were 186 deaths reported to the Coroners Court for investigation during the period 21–30 November 2016. This is 12 more than the number expected, based on the average for the same period over the previous three years (Figure 54).

In 2013, of the 192 cases reported to the coroner, two were reported with asthma as a primary cause of death. In 2014 and 2015 there were 185 and 145 cases reported to the Coroners Court of which zero and one death were reported with asthma as a primary cause of death, respectively. Noting that a coronial investigation is yet to be completed, there have been nine asthma-related deaths reported to the Coroners Court for 21–30 November 2016. This is a marked increase on the number of asthma-related deaths reported in this period in previous years (Figure 55).

Further examination of the reported causes of death for these nine people indicates that eight of the nine are thought to be related to the epidemic thunderstorm asthma event and are included in the thunderstorm asthma coronial investigation.

Of note, a further death that occurred in January 2017 is also thought to be related to the epidemic thunderstorm asthma event and is included in the coronial investigation. This death occurred outside the 21–30 November timeframe and is not captured in this data.

Figure 54: All deaths reported to the Coroners Court of Victoria, 21–30 November 2013–2016

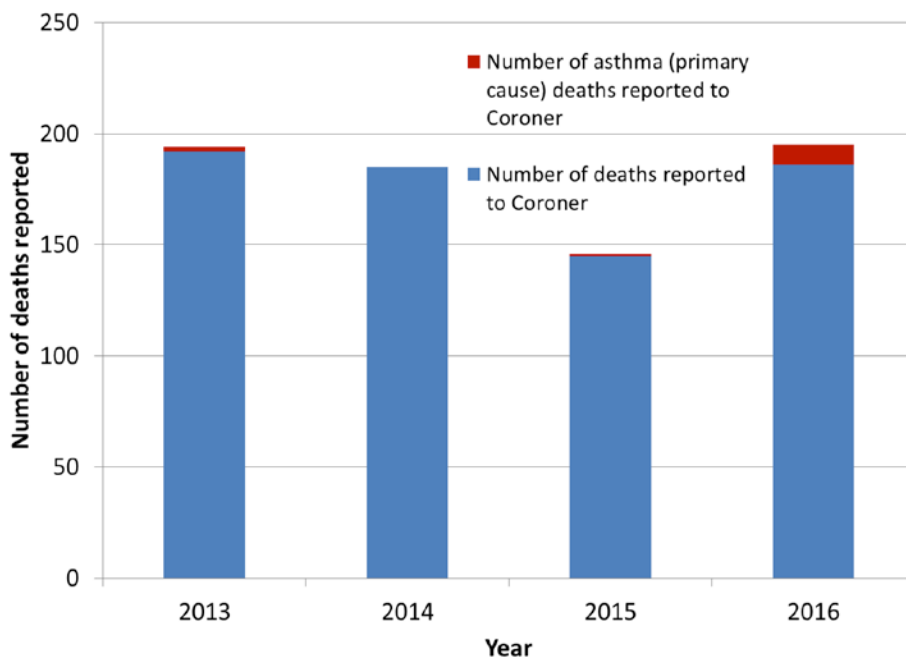
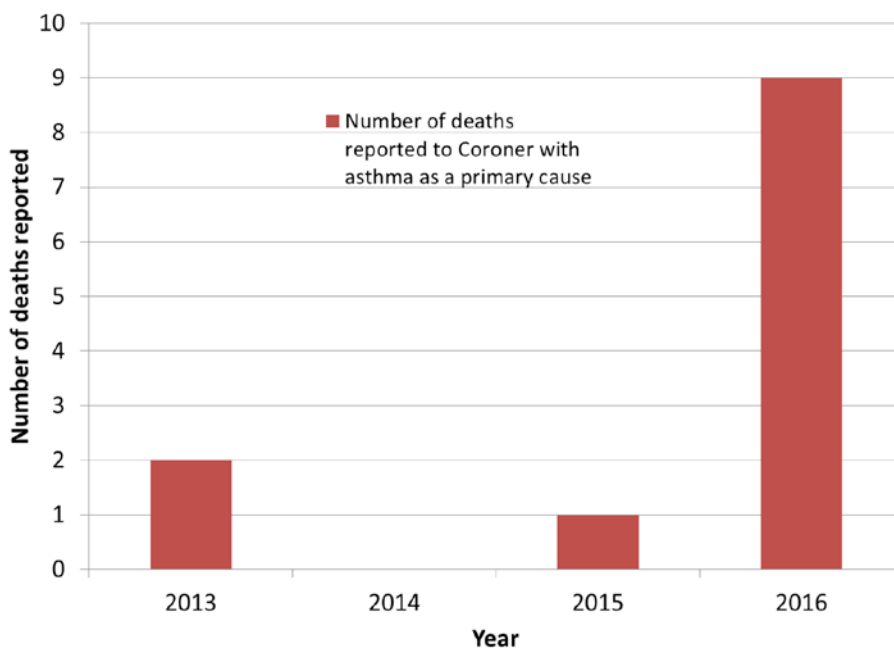


Figure 55: Deaths reported to the Coroners Court of Victoria with asthma as a primary cause of death, 21–30 November 2013–2016





### **Victorian Registry of Deaths, Births and Marriages**

Victorian mortality data is collated by the Victorian Registry of Births, Deaths and Marriages and supplied to the Department of Health and Human Services to enable the Secretary to the department to perform their functions under legislation. Death certificates are required to be completed by a registered medical practitioner within 48 hours of a death and then forwarded to the registry. The registry includes all deaths that occur in Victoria. It may also include deaths that occurred overseas where the deceased was either a Victorian resident or owned property in Victoria.

De-identified death data was requested from the department's Centre for Victorian Data Linkage Unit for November 2016 and November 2013, 2014 and 2015 for comparison. This included de-identified demographic details of the deceased and their cause of death. This data was used to examine the total number of deaths and asthma-related deaths that occurred following the epidemic thunderstorm asthma event. The death registration from the data and unregistered deaths reported by the Coroners Court of Victoria was included.

### **Total deaths**

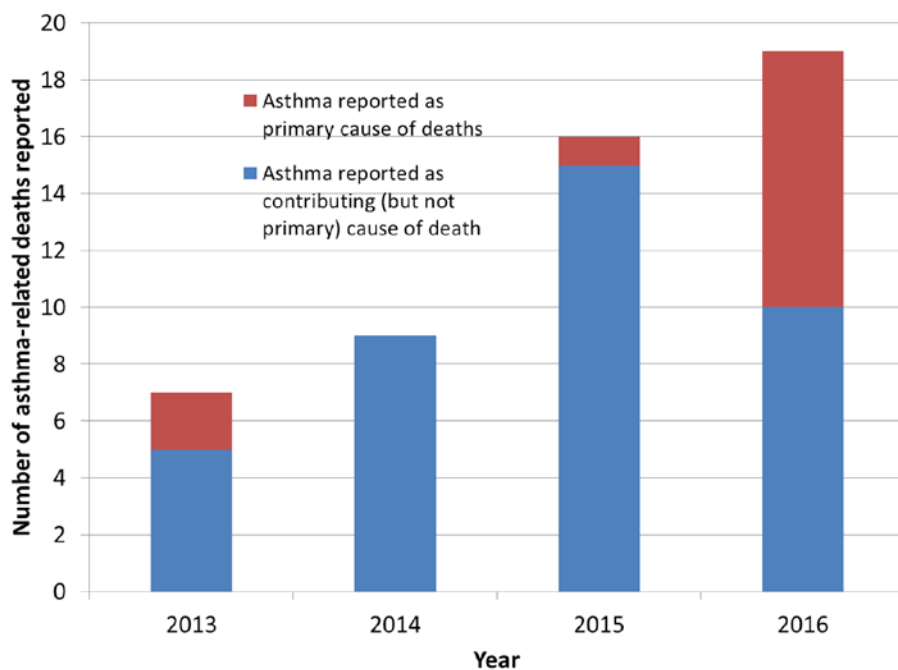
Deaths data from the Victorian Registry of Births, Deaths and Marriages includes data from the Coroners Court of Victoria. Death registrations from the registry and deaths that were reported to the Coroners Court between 21 and 30 November but were not registered with the registry as at 24 January 2017 are presented in this section. Together, these data provide the best estimate available of the total number of deaths and total number of asthma-related deaths for the period of interest.

In total, 1,056 deaths were reported in Victoria from 21 to 30 November 2016, which was 27 (2.6 per cent) more than the number expected based on the average for the same period over the previous three years.

### Asthma-related deaths

From 21 to 30 November 2016, 19 deaths are currently recorded with asthma as a contributing or primary cause of death (Figure 56). Asthma was a *primary* cause of death in nine of these cases. In total, there were nine more asthma-related deaths (*contributing* or *primary* cause) than was expected in this period, based on the average for the same period over the previous three years. All nine deaths with asthma reported as a primary cause of death in 2016 have been referred to the Coroners Court.

Figure 56: Asthma-related deaths in Victoria, 21–30 November 2013–2016

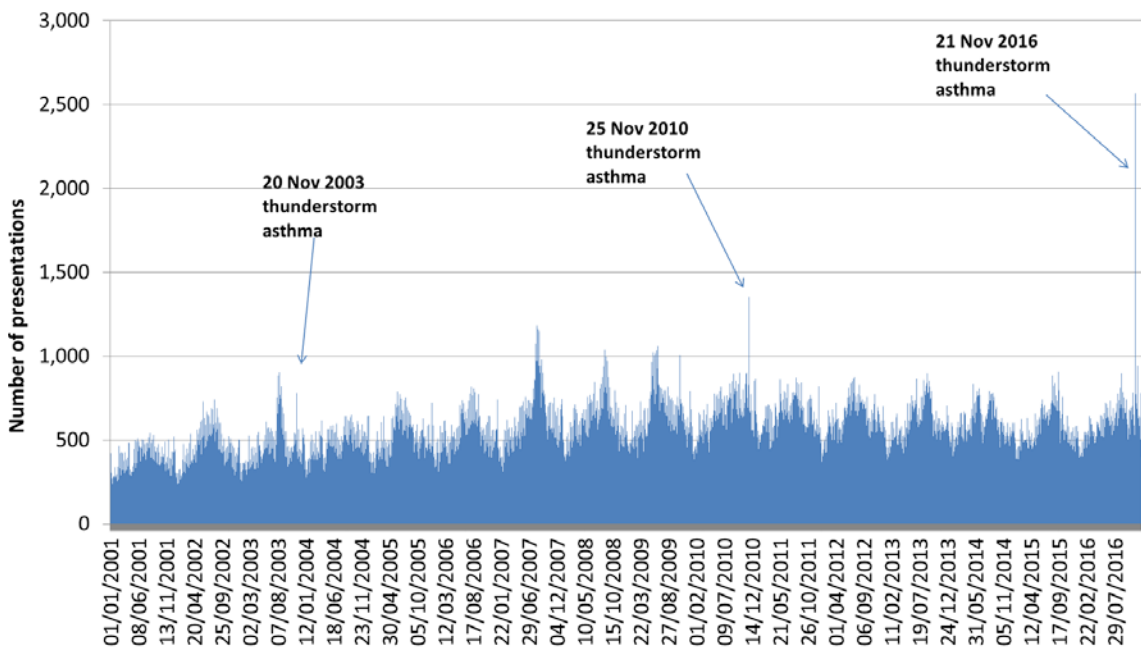


## Comparison of November 2016 event with previous reported epidemic thunderstorm asthma events

As described earlier, smaller epidemic thunderstorm asthma events have previously been reported in Melbourne. Peer-reviewed literature suggests these events were on a far smaller scale and far less intense than the event in November 2016. Examination of emergency department presentation data from previous events also supports this conclusion.

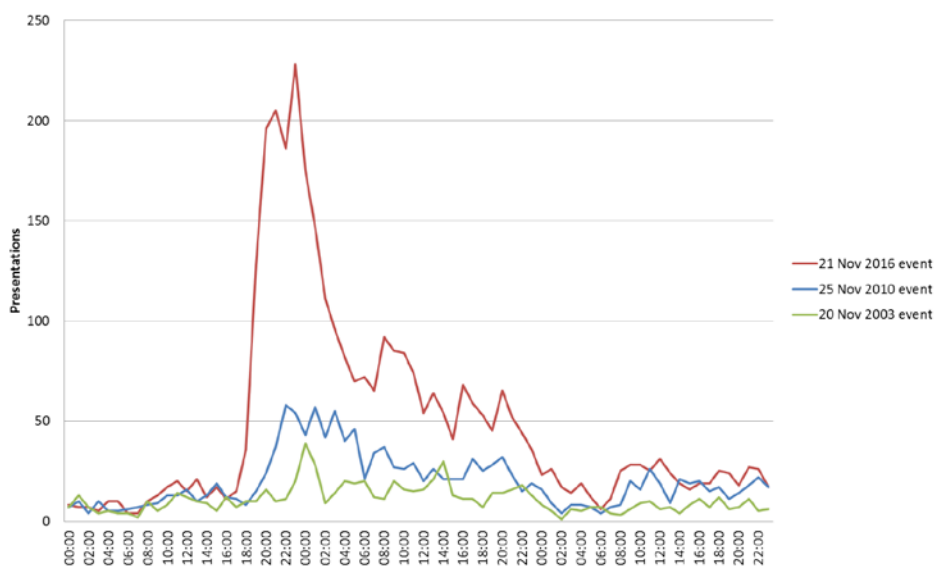
Figure 57 shows respiratory-related presentations to Victorian public hospital emergency departments between January 2001 and November 2016. Total presentations on the two reported thunderstorm asthma events are marked, indicating the increase in respiratory cases on both days. However, the number of presentations on 21 November 2016 are far in excess of these previous two events.

**Figure 57: Respiratory and 'nil diagnosis' presentations to Victorian emergency departments, 2001–2016**



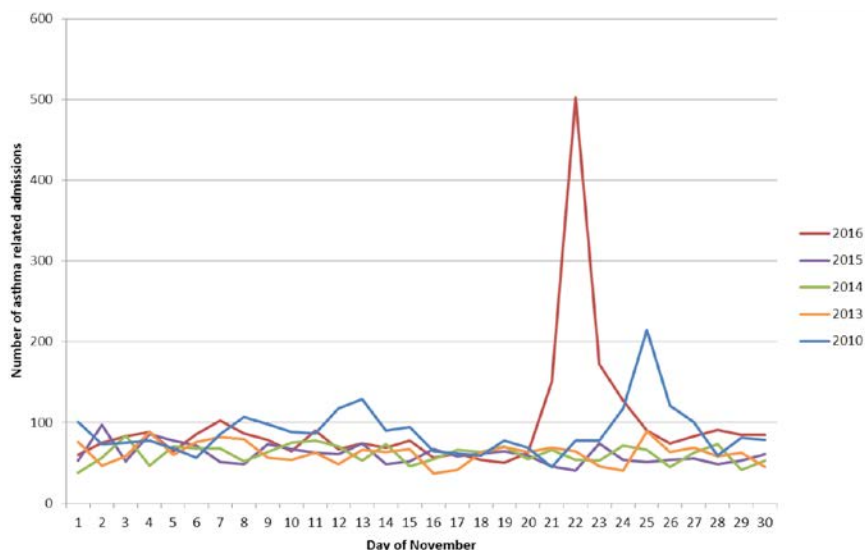
In each of the 2003 and 2010 epidemic thunderstorm asthma events, emergency department presentations were elevated in early evening and overnight (Figure 58).

**Figure 58: Respiratory presentations and 'nil diagnosis' to Victorian public hospital emergency departments on the day of previously reported epidemic thunderstorm asthma events (and the following 48 hours)**



Admission data from November 2010 has also been sought to examine the relative impact of the 2010 event on hospital admission rates (Figure 59). A clear peak in asthma-related admissions can be seen on 25 November 2010. Similarly to November 2016, asthma-related admission rates throughout November in 2010 were elevated, including in the period preceding the epidemic thunderstorm asthma event.

**Figure 59: Asthma-related hospital admissions for November 2013–2016 and November 2010 (for all Victorian hospitals)**



# Conclusion

This report documents the population health impact of the largest epidemic thunderstorm asthma event reported in the world. The legacy of this event will be long standing and widespread.

Epidemic thunderstorm asthma is now recognised as a broad and significant risk for the Victorian community, during the grass pollen season. It will require a similarly broad response with planning and preparations across all relevant sectors, particularly emergency and health services.

The infrequent nature of these events means that attention must be paid to ensuring that the lessons learnt and the system adaptations and developments underway are sustained into the long term.

Increasing awareness, knowledge and preparedness for epidemic thunderstorm asthma is critical to increasing community resilience and mitigating this risk. Optimising asthma and hay fever management will decrease the impact of any subsequent events and will improve the overall health and wellbeing of people with these conditions in-between events.

Similarly, relevant institutions, services and agencies need to develop and implement suitable policies and response protocols to address this hazard.

This report has shown that we as individuals and as a community, need to be aware of epidemic thunderstorm asthma in south east Australia and before every pollen season, we need to prepare in order to respond effectively.

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