

Climate Change and Extreme Weather Events in Australia

Impact on Allergic Diseases



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KEYWORDS

- Australian climate • Extreme weather events • Respiratory health effects
- Aeroallergens

KEY POINTS

- Climate change factors have resulted in increased extreme weather events on the Australian continent with significant impact on respiratory health in particular.
- Extreme bushfire events leading to dramatic smoke plumes and the resulting air pollution affect the health and well-being of thousands of people.
- The worst ever epidemic thunderstorm asthma event occurred in Melbourne, Australia in 2016 at the peak of the pollen season having catastrophic consequences, as emergency services were overwhelmed and several asthma deaths were recorded.
- Climate change factors will cause alterations in plant distribution, pollen and fungal exposure, necessitating careful, and longitudinal aerobiological studies in order to prepare for the changes in respiratory allergic diseases that may arise as a consequence of such changes.

INTRODUCTION

Changes in climate are affecting, and will continue to impact, various disease states. Allergic respiratory disorders such as allergic rhinoconjunctivitis and asthma are affected both directly and by the various consequences that result from climate change. There are 2 aspects of climate change affecting respiratory disorders that will be briefly explored in this paper: firstly, the consequences of extreme weather events and secondly, the change in distribution of airborne allergens that results from various climate change factors.

OUR CHANGING CLIMATE

Several climate change-related predictions and observations have been documented for the Australian continent by the Intergovernmental Panel on Climate Change,¹ the

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most authoritative international body reporting on the science behind climate change and its various impacts and consequences, in conjunction with the The Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Bureau of Meteorology who have also documented several scenarios. Global warming has directly affected Australians with extreme weather events such as drought, major bushfires, thunderstorms, cyclones, and flooding.² Australian average surface air temperature has increased by 0.9°C since 1910 and may increase by 1°C to 5°C by 2070. The years 2013 to 2014 were the warmest 2-year period in Australia's recorded history, with 2015 and 2016 not far behind.³ In recent decades more extremely warm months have occurred than extremely cool ones. Many heat-related records have been broken in the last 7 years. Continued increases in mean and daily minimum and maximum temperatures are predicted throughout all regions with high confidence. Australian average rainfall has been increasing since the 1970s, mainly due to an increase in wet season rain in northern Australia. During the cooler months, rainfall has declined in the south-east and south-west of the continent. Extreme rain events are projected to become more intense.³ Tropical cyclones are predicted to become less frequent but more intense (category 3–5), with a greater proportion of severe storms reaching further south.^{3,4} In Southern Australia, time in drought is projected to increase with the occurrence of more extreme droughts in line with the decrease in rainfall in these regions.

Extreme weather events such as cycles of severe drought and damaging flooding experienced in Australia are attributed to the El Nino Southern Oscillation (ENSO), which is determined by the atmospheric circulation patterns over the Pacific Ocean. Two phases of ENSO are recognized; the EL Nino phase causes severe drought over the eastern parts of the continent, whereas the La Nina is associated with warmer surface waters in the Pacific Ocean resulting in extra atmospheric moisture and higher rainfall over much of the continent leading to flooding in vulnerable areas. Changes associated with global warming are predicted to intensify the oscillations, leading to cycles of more intense droughts and flooding events.

Southern and Eastern Australia will experience conditions conducive to more severe bushfires because of warming and drying of vegetation leading to greater availability of fuels, and this has already occurred with severe fires in 2009 (the Black Saturday fires in Victoria) leading to terrible loss of life and property and again in the summer of 2019 to 2020 in NSW, Victoria, ACT and South Australia with similarly severe losses.^{5–7}

Weather events such as those described earlier have immediate consequences on many aspects of human health but the aftermath of drought, fires, and floods also threaten our well-being. By destruction of crops and infrastructure, food supplies are affected and infectious diseases become a threat. Persisting poor air quality has a major impact on respiratory and cardiovascular health.

IMPACT OF EXTREME WEATHER EVENTS ON ALLERGIC RESPIRATORY DISORDERS

For individuals with allergic disorders, there are particular health considerations around extreme weather events such as bushfires, thunderstorms, and flooding.

OCCURRENCE OF WILDFIRES

Weather conditions caused by climate change will increase the frequency of extreme bushfires around the world and this is particularly so in Australia where longer fire seasons, starting earlier in the spring and summer, are predicted to occur with increasing frequency. Research suggests that as global temperatures increase, these events will become more frequent leading to lower rainfall and creating a drier feedstock for

extreme bushfires. In turn, bushfire smoke and the resulting air pollution affects the health and well-being of thousands of people.^{8,9}

Bushfires have always been a part of the Australian landscape but as Australia's climate changes, one of the most significant and devastating consequences will be the occurrence of more frequent bushfires that are likely to be fiercer and difficult to control.¹⁰ Large wildfires tend to occur during drought periods and in severe fire weather, driven by high temperatures, low relative humidity, and strong winds.¹¹

Bushfire Smoke Composition

Landscape fire smoke is a complex and dynamic mix of energy, water vapor, gases, and aerosols. Many of the gaseous compounds are strong greenhouse gases and are toxic to humans. The public health impacts of air pollution, including landscape fire smoke, have become more clearly characterized over recent decades.^{12–14} Large human populations including those distant from the fires, can be exposed to the resulting smoke pollution causing measurable increases in mortality and morbidity.^{15–17}

Although smoke exposure might cause minor irritation of the eyes or throat in healthy people, it can precipitate severe breathing difficulty in a person with asthma or other respiratory disease. The health impacts of air pollution derived from wildfires are driven by various factors such as the chemical composition and concentrations of pollutants in the smoke plume and the intensity and duration of smoke exposure during an event and the extent to which individuals can protect themselves from that exposure.¹² Health impacts are also tied to the prevalence of risk factors in the population, such as cardiovascular¹⁸ and lung diseases, diabetes,¹⁹ older or younger age, and lower socioeconomic backgrounds. Smoke exposure is known to disproportionately affect people with lung diseases,²⁰ and the evidence concerning impacts on heart diseases is emerging.²¹

PM2.5 Exposure

The health effects best studied as a result of bushfire smoke exposure are those resulting from exposure to PM2.5.¹² These particles penetrate into the small airways causing inflammatory changes as well as having an effect on the immune system. People who have chronic lung conditions such as asthma, chronic obstructive pulmonary disease, and emphysema are most affected in these situations.¹³ Other detrimental health effects of PM2.5 include promotion of inflammation and blood coagulation; impairment of the respiratory, cardiovascular, and autonomic nervous systems; and increased risk of genetic mutations.¹² Short-term exposure is probably not hazardous for healthy individuals but for those with respiratory disease including asthma it may provoke severe respiratory compromise. For those who suffer from chronic allergic rhinoconjunctivitis, further irritation of conjunctiva and nasal mucosa is inevitable.

As in other parts of the world, in South Eastern Australia, bushfire smoke exposure has been linked to increase in mortality.²² When considering health impacts, there are no safe levels of PM2.5 so those with underlying respiratory disease are at risk regardless of whether the source is wildfire or controlled burning.

A long-term practice for mitigation of wildfires has been that of controlled burns to reduce the fuel load of a particular area at a time when it is safe to perform the controlled burn. Days with ideal weather conditions when temperatures are mild and there is no wind can be chosen for the activity; the at-risk population can be warned ahead of time to ensure use of preventative medications and "safe havens" may be created, either in a controlled environment or via the supply of protective respiratory equipment. Wild fires and controlled burns generally result in different smoke

exposures to human populations. When wildfires occur, smoke and pollution are distributed over a very wide area, so large populations are affected.¹²

THUNDERSTORMS

On 21 November 2016 the worst ever epidemic thunderstorm asthma event occurred in Melbourne, Australia. It had catastrophic consequences, as ambulance services and emergency services were overwhelmed with calls for help. Hundreds of people presented to emergency departments throughout the city; 35 were admitted to intensive care units and 10 victims died. From previous thunderstorm events, several factors were identified that were prerequisites for such an event—particular types of thunderstorm activity with outflows, high aeroallergen exposure, and a susceptible population.²³ In Melbourne on that particular afternoon a powerful front hit Melbourne causing a sudden drop in temperature, an increase in humidity, and a concentration of particulate matter. This occurred at the height of the Melbourne pollen season when grass pollen (predominantly perennial rye grass) levels were extremely high. The timing coincided with the end of the working day, so many people were outdoors, traveling home.

Thunderstorm asthma events are not unusual in some parts of Australia particularly in the southern regions.²⁴ Previous studies had shown that fine starch granules, less than 2.5 μm , are released from rye grass pollen following wetting,^{25,26} and with certain weather conditions, these are available to be inhaled deep into the lower airways. In susceptible, sensitized individuals such as those with seasonal allergic rhinitis and asthma this can precipitate a severe asthma attack.

CYCLONES, FLOODING, AND FUNGAL EXPOSURE

Flooding events have been the most common type of disaster globally and are expected to increase in intensity and in frequency due to increasing sea levels and more extreme rain events.¹ The numerous effects on short-term and long-term health resulting from flooding have been documented.²⁷ Respiratory effects are of our particular concern. Mold inhalation can cause or exacerbate asthma and other respiratory illnesses. Asbestos and other toxins such as lead and arsenic are often liberated by these events and require precautions. As expected, there was documented heavy fungal growth after the devastating flood in New Orleans in 2005 (Hurricane Katrina). This led to marked levels of indoor fungi, endotoxins, and fungal glucans all of which are associated with adverse respiratory health outcomes.²⁸

The workers conducting remediation in mould-affected buildings are at particular risk, so require adequate respiratory protection to carry out remediation. Increased respiratory symptoms were demonstrated in workers associated with clean up after Hurricane Sandy in the United States in 2012.²⁹ Hurricane Maria in Puerto Rico in 2017 was also associated with increased reports of asthma and respiratory symptoms.

Cyclones and extremely heavy rain periods resulting in flooding are all too common occurrences in Australia. Tropical cyclones are intense weather systems that occur in tropical regions of the world, including around Northern Australia. They are deep low pressure systems with extreme winds, rainfall, and destructive waves that cause coastal hazards such as storm surges, flooding, and coastal erosion. Recent studies suggest that there has been an increase in the occurrence of high-intensity tropical cyclones globally offset partly by a decrease in the number of weaker tropical cyclones. The most intense tropical cyclones have increased their wind speeds in all ocean basins including the Pacific.

Tropical cyclones in the Australian region are influenced by several factors and in particular variations in the El Niño—Southern Oscillation. In general, more tropical cyclones cross the coast during La Niña years and fewer during El Niño years. Other important factors include changes in sea surface temperature and changes in deep convection.³ The Bureau of Meteorology advises that the Australian region (90–160°E) has, on average, 13 cyclones a year. Half of these occur in the Indian Ocean, off Western Australia. However, tropical cyclone frequency in the Australian region varies considerably from year to year due to the influence of naturally occurring climate drivers.³ Increased rainfall intensity from tropical cyclones is pertinent to Australia, since these storms have historically been associated with major flooding. In addition, increases in storm surges and extreme sea levels are very likely to occur in association with tropical cyclones under future climate change. This change is independent of changes in tropical cyclone intensity and is directly related to increases in global mean sea level due to global warming.

Australia has a significant history of devastating flooding events costing billions of dollars and causing long-lasting health impacts. Tropical cyclones are among the costliest natural disasters to regularly affect Australia. For instance, insured losses from Cyclone Debbie in Queensland exceeded \$1 billion in 2017, making it the most expensive cyclone in the state's history. Cyclone Yasi 2011 destroyed almost 150 homes and a further 2275 homes sustained moderate damage and left another 650 uninhabitable when it crossed the far north Queensland coast.^{30–32}

Fungal growth and exposure may also be an issue for many people after heavy rains, even those who have not been affected by floodwaters. It is also the scourge of many Australian homes year-round.³³ Fungi in damp buildings can trigger nasal congestion, sneezing, cough, wheezing, and respiratory infections. It can also worsen asthma and allergic conditions.³⁴ People most at risk from detrimental effects of fungal overgrowth and exposure include those with weakened immune systems; allergies; severe asthma; and chronic, obstructive, or allergic lung diseases. Understanding extreme weather hazards such as tropical cyclones and how they may change as the climate continues to warm is valuable for increasing Australia's preparedness and resilience to such events.

IMPACT OF INCREASING POLLUTION LEVELS

The generation of greenhouse gases by human activity contributes significantly to climate change. Pollutants such as ozone, nitrogen dioxide, and fine particulate matter are generated from motor vehicles and industrial processes. With increasing temperatures and longer periods of sunlight there will be more pronounced peaks in ozone concentration.³⁵ There is epidemiologic evidence linking the occurrence of asthma, asthma exacerbations, and hospital presentations as well as other allergic conditions with increasing air pollution.^{36,37} Experimental studies have demonstrated that pollutants can induce development of numerous hallmarks of airway inflammation and can stimulate irritant receptors in the lung.³⁸ For certain pollutants, particularly ozone and PM2.5, adjuvant effects that may enhance the development of allergy to certain pollen have been observed.³⁹

CHANGES IN AEROALLERGEN DISTRIBUTION AND ALLERGENICITY

Changing climatic conditions such as increasing atmospheric carbon dioxide (CO₂) concentrations and temperatures are causing shifts in the geographic distribution of certain plant species and changes in the length of pollen seasons globally.^{40–42} There are several examples of this; the most significant one for respiratory allergy is the

expansion of ragweed into areas in Central and Eastern Europe over the last 50 years.⁴³ A variety of changes in distribution have been documented for several trees including Birch⁴⁴ where forests are retreating to more northern latitudes and for grasses⁴⁵ and weeds.⁴⁶

Several climate change factors have been linked to changes in aeroallergen concentration and potency. Temperature increases and elevation of CO₂ levels in the atmosphere have been associated with longer flowering periods for some allergenic plants, with some data suggesting increased pollen production and even an increase in the allergenicity of certain pollen. For ragweed, increasing CO₂ levels resulted in increasing levels of the major allergen Amb a1.^{47–50}

Lengthening of the pollen season has been demonstrated in the United States and in Europe where long-term pollen counting records exist.⁵¹ Zhang and colleagues⁴⁸ have described lengthening of the ragweed pollen season in North America, a change that is more pronounced in the northern locations such as regions in Canada. Others have noted an earlier start to the spring pollinating season.⁵¹ By documenting the phenology of several flowering plant species, Fitter and Fitter⁵² have described advancement in flowering seasons of many species in Britain. Ariano and colleagues⁵³ have demonstrated not only a lengthening of the pollen season but also increased total pollen load and an increase in pollen sensitization among the population in Italy.

Australia has one of the highest prevalence rates for both allergic rhinitis and asthma, so many people are likely to be affected by changes in aeroallergen distribution and potency. Studies in Australia have demonstrated relationships between grass pollen and fungal spore exposure and hospitalizations for asthma.^{54,55}

Far less systematic study has been done in Australia to map changing plant distributions although efforts at mapping seasonal patterns of grass pollen distribution have commenced.⁵⁶ Methods that may be used to enhance our ability to issue pollen forecasts are also being examined.⁵⁷

Many of the allergenic species in this country have been introduced from the Northern Hemisphere. Without natural predators they have become established in a new environment and have the capacity to induce sensitization and allergic symptoms. One example of this is the plant *Echium plantagineum*, which after it was introduced to the southern states of Australia as a garden ornamental in the mid-1800s, became prolific and overran pasture lands. Its allergenic potential has been demonstrated and its pollen contributes to seasonal allergy in the southern states.⁵⁸

Ragweed has also been introduced and is slowly spreading in certain regions. Increasing CO₂ levels can be expected to alter the distribution of various grass species with higher CO₂ favoring C4 grasses over the C3 species. Nothing is known about how climatic factors will alter the distribution and flowering of native Australian species and indeed, very little is known about their allergenic potential. Furthermore, there is very little published material on the aerobiology of various allergenic fungi and even less about fungal distribution and changes over time yet there are known associations between fungal exposure and asthma presentations.⁵⁵

These deficiencies highlight the great importance for funding systematic study of the aerobiology of the various disparate regions of the continent so that changes in pollen and spore levels and composition over time and with the changing climate may be tracked and mitigation strategies used where necessary. Prevalence of allergic disease is already high in Australia and if the present situation continues and in fact worsens, as is predicted, our medical workforce will be ill equipped to cope with the greater demand from patients suffering chronic allergic and respiratory conditions. There is an imperative to begin up-skilling and training our

medical staff to meet the challenge of yet further increases in patients presenting with allergic and other respiratory disorders, an inevitable consequence of our changing climate.

Clinics Care Points

- Climate change factors are already affecting the lives of those with respiratory diseases.
- Early warning systems for bushfire smoke and high-pollution days need to be refined, and mitigating measures to effectively minimize these impacts for vulnerable people require further study.
- Plant distribution and pollen and fungal exposure will change as our climate is affected. Long-term funding commitments are required for adequate monitoring of these changes allowing for development of reliable predictive models.

DISCLOSURE

The author declares no conflicts of interest.

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