BE PREPARED: CLIMATE CHANGE AND THE SOUTH AUSTRALIA BUSHFIRE THREAT

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Authorship:
Professor Lesley Hughes

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Professor Lesley Hughes
Climate Councillor

Introduction

Residents of South Australia have experienced the serious consequences of bushfires. In 2005 the Black Tuesday bushfires on the Eyre Peninsula resulted in the tragic loss of nine lives and estimated damages of $41 million (2011$). At the beginning of 2014 several bushfires raged across the state, burning tens of thousands of hectares of land, destroying properties and injuring firefighters and residents.

Australians have always lived with fire and its consequences, but climate change is increasing fire danger weather and thus the risk of fires. It is time to think very seriously about the risks that future fires will pose.

We first describe the background context of fire and its history in South Australia. We then outline the link between bushfires and climate change, before considering how bushfire danger weather is increasing in South Australia and what this means for the immediate future. We explore the impacts of fire on people, property, water supply and biodiversity, before considering the future influence of climate change on bushfires, and the implications for South Australian fire managers, planners and emergency services.

Key Findings

1. **Climate change is already increasing the risk of bushfires in South Australia.**
   - Extreme fire weather has increased over the last 30 years in South Australia.
   - Australia is a fire prone country and South Australia has always experienced bushfires. Today climate change is making hot days hotter, and heatwaves longer and more frequent, with increasing drought conditions in Australia's southeast. The hotter, drier conditions are increasing the risk of high fire danger weather in South Australia.
   - 2013 was South Australia's hottest year on record and in Adelaide the average intensity of heatwaves has increased by 2.5°C. These conditions are driving up the likelihood of very high fire danger weather in the state.
2. **The fire season in South Australia is starting earlier and lasting longer. Fire weather has been extending into Spring and Autumn.**
   - This year, the bushfire season will start early in seven of fifteen districts in South Australia. These districts include the Eastern Eyre Peninsula, Kangaroo Island, the Lower South East, the Mount Lofty Ranges, the North East Pastoral, Riverland and the West Coast.
   - The fire season will continue to lengthen into the future, straining South Australia's existing resources for fighting and managing fires.
3. **Recent severe fires in South Australia have been influenced by record hot, dry conditions.**
   - Record breaking heat and hotter weather over the long term in South Australia has worsened fire weather and contributed to an increase in the frequency and severity of bushfires.
   - In January 2005, temperatures of over 40°C contributed to severe bushfires on the Eyre Peninsula, which resulted in the tragic loss of nine lives and estimated damages of $41 million (2011$).
4. **The total economic costs of the South Australian bushfires in 2014 are projected to be $44 million. By around the middle of the century these cost will almost double.**
   - Bushfires cause significant economic damage, estimated at $337 million per year (2011$) in Australia. With a forecast growth in costs of 2.2% annually between 2014 and 2050, the total economic cost of bushfires is expected to reach $800 million annually by mid-century. In South Australia bushfires are projected to cost $44 million in 2014 (2011$).

- These state and national projections do not incorporate increased bushfire incident rates due to climate change and could potentially be much higher.

5. In the future, South Australia is very likely to experience an increased number of days with extreme fire danger. Communities, emergency services and health services across South Australia must prepare.

- Fire severity and intensity is expected to increase substantially in coming decades, especially in those regions currently most affected by bushfires, and where a substantial proportion of the Australian population lives, such as South Australia.
- Increased resources for our emergency services and fire management agencies will be required as fire risk increases. By 2030, it has been estimated that the number of professional firefighters in Australia will need to approximately double (compared to 2010) to keep pace with increased population, asset value, and fire danger weather.

6. This is the critical decade

- Australia must strive to cut emissions rapidly and deeply to join global efforts to stabilise the world's climate and to reduce the risk of even more extreme events, including bushfires.

1. The nature of bushfires

Fire has been a feature of the Australian environment for at least 65 million years (Cary et al. 2012). Human management of fires also has a long history, starting with fire use by indigenous Australians ("fire-stick farming") up to 60,000 years ago. Between 3% and 10% of Australia's land area burns every year (Western Australian Land Information Authority 2013).

In Australia, the Forest Fire Danger Index (FFDI) is used to measure the degree of risk of fire in our forests (Luke and Macarthur 1978). The Bureau of Meteorology (BoM) and fire management agencies use the FFDI to assess fire risk and issue warnings. The index was originally designed on a scale from 0 to 100, with fires between 75 and 100 considered 'extreme'. The unprecedented ferocity of the 2009 Black Saturday bushfires in Victoria saw a new 'catastrophic' category added to the FFDI for events exceeding the existing scale.

The concept of "fire regimes" is important for understanding the nature of bushfires in Australia, and for assessing changes in fire behaviour caused by both human and climatic factors (Figure 2). A fire regime describes *a recurrent pattern of fire*, with the most important characteristics being the frequency, intensity, and seasonality of the fire. Significant changes in any of these features of a fire regime can have a very important influence on its ecological and economic impacts (Williams et al. 2009).

Figure 1: A Firefighter at work in South Australia

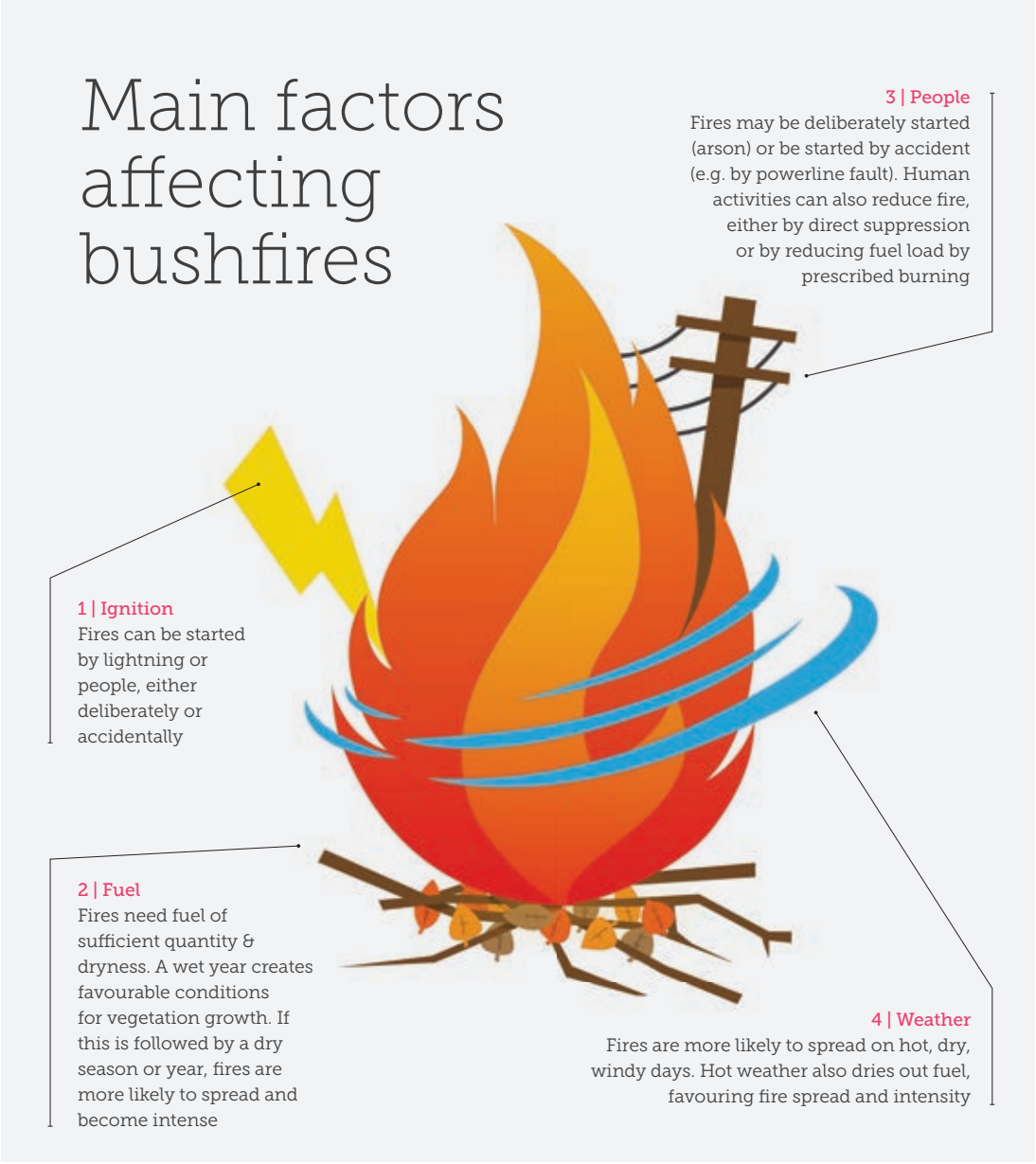

Figure 2: Main Factors Affecting Bushfires

Fire is a complex process that is very variable in space and time. A fire needs to be started (ignition), it needs something to burn (fuel) and it needs conditions that are conducive to its spread (weather and topography) (see Figure 2). Fire activity is strongly influenced by weather, fuel, terrain, ignition agents and people. The most important aspects of weather that affect fire and fuels are temperature, precipitation, wind and humidity. Once a fire is ignited, very hot days with low humidity and high winds are conducive to its spread. The type, amount, and moisture level of fuel available are also critical determinants of fire behaviour, extent and intensity. The relationship between rainfall and

fuel is complex. Wet seasons can lead to increased plant growth and therefore increase fuel buildup in the months or years before a fire is ignited (Bradstock et al. 2009). Warmer temperatures and low rainfall in the period immediately preceding an ignition, however, can lead to drier vegetation and soil, making the existing fuel more flammable. Warmer temperatures can also be associated with a higher incidence of lightning activity (Jayaratne and Kuleshov, 2006), increasing the risk of ignition.

As fire weather conditions become more severe, fuel moisture content declines, making the fuel more flammable. By contrast, in arid regions, vegetation and thus fuel in most years is sparsely distributed and fires, if ignited, rarely spread far. In Australia's southeast, fires are common in the heathlands and dry sclerophyll forests, typically occurring about every 5 to 30 years, with spring and summer being peak fire season (Clarke et al. 2011; Bradstock et al. 2012).

People are also a very important component of the fire equation. Many fires are either deliberately or accidentally lit, and in places where population density is high, the probability of a fire igniting increases close to roads and settlements (Willis 2005; Penman et al. 2013). Some of Australia's most catastrophic bushfires have been ignited by powerline faults. But people also play an important role in reducing fire risk, by vegetation management including prescribed burning to reduce fuel load and conducting fire suppression activities. Interventions such as total fire ban days also play a pivotal role in reducing ignitions under dangerous fire conditions (Climate Council 2014a).

Figure 3: A bushfire near Adelaide

South Australia is no stranger to bushfires. The state has been affected by bushfires throughout history. In 1983 the Ash Wednesday fires in Victoria and South Australia led to the loss of 75 lives, the destruction of over 2,300 homes and had an estimated cost of $307 million (2011$) in South Australia (AEM 2014a).

In 2005 the Black Tuesday bushfires burnt approximately 82,000 hectares and resulted in 110 injuries and the loss of nine lives (AEM 2014b). More recently, the 2011-2012 fire season saw over 5 million hectares of land burnt and at the start of 2014, several significant bushfires burnt over 100,000 hectares and resulted in 24 injuries (SACFS 2014a).

2. What is the link between bushfires and climate change?

Figure 4: An outback fire in Renmark SA

A fire needs to be started (ignition), it needs something to burn (fuel) and it needs conditions that are conducive to its spread (weather) (Section 1). Climate change can affect all of these factors in both straightforward and more complex ways.

The role of climate change in ignition is likely to be relatively small compared to the fuel and weather, but may still be significant. For example, lightning accounts for ~27% of the ignitions in the Sydney region (Bradstock 2008) and the incidence of lightning is sensitive to weather conditions, including temperature (Jayaratne and Kuleshov 2006). Climate change can also affect fuel. For example, a lack of rainfall can dry out the soil and vegetation, making existing fuel more combustible. But whilst climate change can affect ignition and fuel, it is the impact of climate change on weather that has the most significant influence on fire activity (Climate Council 2014a).

Very hot, dry and windy days create very high bushfire risk. The most direct link between bushfires and climate change therefore comes from the relationship between the long-term trend towards a warmer climate due to increasing greenhouse gas emissions – the increasing amount of heat in the atmosphere – and the incidence of very hot days. Put simply, climate change is increasing the frequency and severity of very hot days (IPCC 2012; 2013), and is driving up the likelihood of very high fire danger weather (see Section 3). The 2005 Black Tuesday bushfires on the Eyre Peninsula illustrate the role of weather conditions in affecting fire severity. In January 2005, temperatures of over 40°C contributed to ferocious bushfires on the Peninsula, with heat from the fire exceeding 1000°C and wind speeds of up to 100 km per hour. The fires burnt 82,000 ha and resulted in 110 injuries and the loss of nine lives. The Insurance Council of Australia estimated total damages of $41 million (2011$) (AEM 2014b).

It is important to note that climate change is already increasing the intensity and frequency of some extreme events such as very hot days and droughts. The strength of trends and the confidence in their attribution, however, varies between regions and between different types of event (IPCC 2012; 2013; 2014). Extreme weather events, like bushfires, are influenced by a number of different factors. That's why asking if a weather event is "caused" by climate change is the wrong question. *All* extreme weather events are now being influenced by climate change because they are occurring in a climate system that is hotter and moister than it was 50 years ago (Trenberth 2012). The latest IPCC report confirms with high confidence that climate change is expected to increase the number of days with very high and extreme fire weather, particularly in southern Australia (IPCC 2014).

Climate change is expected to increase the number of days with very high and extreme fire weather, particularly in southern Australia

3. Observations of changing bushfire danger weather in South Australia

Increasing hot days, heatwaves and rainfall deficiencies in South Australia are driving up the likelihood of very high fire danger weather in the state.

While hot weather has always been common in Australia's southeast, it has become more common and severe over the past few decades, including in South Australia (see Figure 6). The southeast of Australia has experienced significant warming during the last 50 years (Timbal et al. 2012). 2013 was the hottest year on record both nationally and in South Australia and mean temperatures in the state were 0.41°C above the previous record set in 2009 (BoM 2014; Climate Council 2014b). Heatwaves in South Australia are also increasing in frequency, intensity and duration. For example, in Adelaide from 1951-2011 the average intensity of heatwaves has increased by 2.5°C (Climate Council 2014b). The IPCC projects with virtual certainty that warming in Australia will continue throughout the 21st century and predicts with high confidence that bushfire danger weather will increase in most of southern Australia, including South Australia (IPCC 2014).

Figure 5: Burned vineyards in South Australia

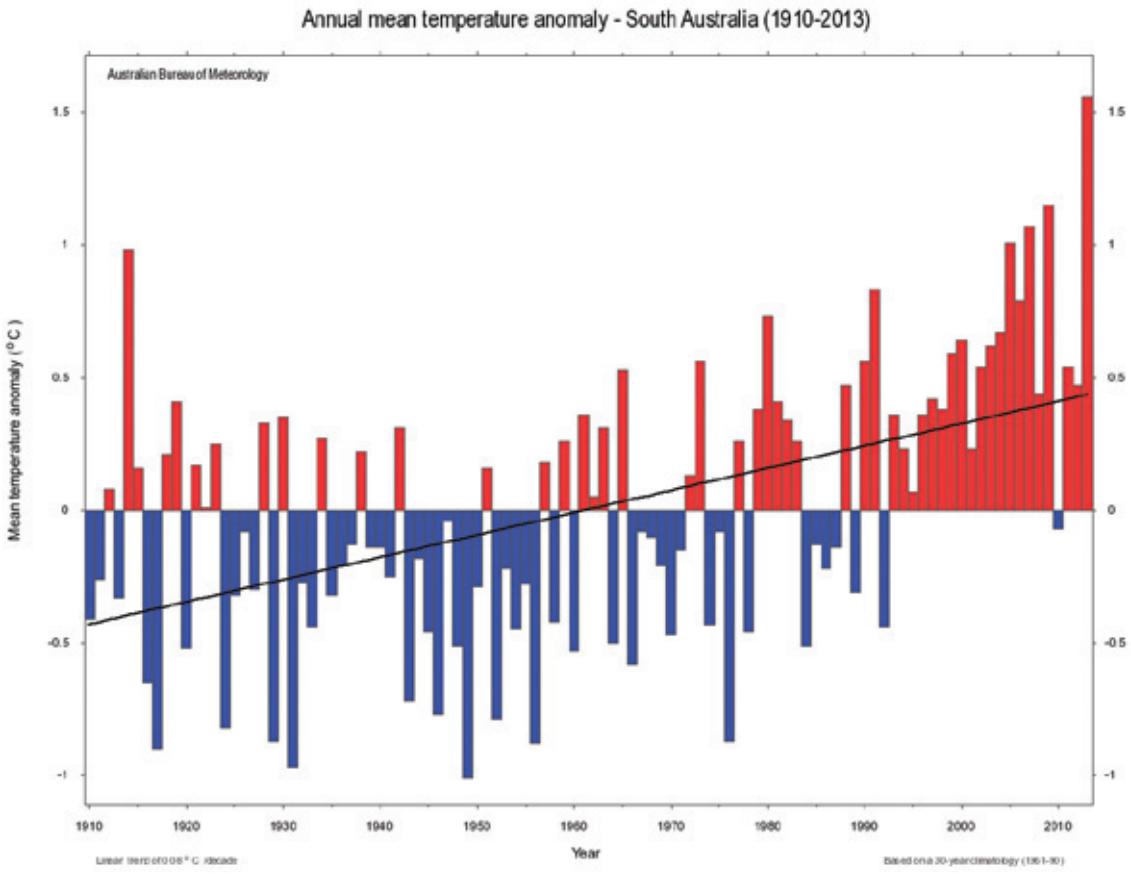

Figure 6: South Australia increasing heat (Australian Bureau of Meteorology). Blue bars indicate years where annual temperatures were below average, and red bars indicate years of above average temperatures.

Much of eastern Australia has become drier since the 1970s, with the southeast experiencing a drying trend due to declines in rainfall combined with increased temperatures (BoM 2013; Climate Commission 2013). Since the mid-1990s, southeast Australia has experienced a 15 percent decline in late autumn and early winter rainfall and a 25 percent decline in average rainfall in April and May (CSIRO & BoM 2014). Much of Australia was drier than normal from mid-2012 with record low July to December rainfall across Central South Australia (Climate Council 2014b). Rainfall since May 2014 has tended to be below average across northern South Australia (Bushfire and Natural Hazards CRC 2014). Long-term rainfall deficits across southern Australia, coupled with above average temperatures, have reduced soil moisture and dried heavy fuels in forests, increasing bushfire potential in parts of South Australia (Bushfire and Natural Hazards CRC 2014). It is very likely that an increased incidence of drought in the southeast - coupled with consecutive hot and dry days - will in turn result in longer fire seasons and an ever larger number of days of extreme fire danger in coming decades (e.g. Clarke et al. 2011; 2013).

The concept of a 'normal' bushfire season is rapidly changing as bushfires continue to increase in number, burn for longer and affect larger areas of land.

The concept of a 'normal' bushfire season is rapidly changing as bushfires continue to increase in number, burn for longer and affect larger areas of land (Bushfire CRC 2014). The influence of hotter, drier weather conditions on the likelihood of bushfire spread in South Australia is captured by changes in the Forest Fire Danger Index (FFDI), an indicator of extreme fire weather. Some regions of Australia, especially in the south and southeast (Victoria, South Australia and New South Wales) have already experienced a significant increase in extreme fire weather since the 1970s, as indicated by changes in the FFDI. The FFDI increased significantly at 16 of 38 weather stations across Australia between 1973 and 2010, with none of the stations recording a significant decrease (Clarke et al. 2013). These changes have been most marked in spring, indicating a lengthening fire season across southern Australia, with fire weather extending into October and March. The lengthening fire season means that opportunities for fuel reduction burning are decreasing (Matthews et al., 2012).

This year, the bushfire season has started early in several parts of South Australia. The state has fifteen districts, and at the time of writing the South Australia Country Fire Authority confirmed that seven of these districts have either already started, or are set to start. These districts include the Eastern Eyre Peninsula, Kangaroo Island, the Lower South East, the Mount Lofty Ranges, the North East Pastoral, Riverland and the West Coast. Total fire bans were also declared across parts of South Australia on the 20th-24th of October as temperatures in the state climbed to above 30°C (SACFS 2014b). The Australia Seasonal Bushfire Outlook for 2014/15 (see Figure 7) projects that due to the hotter, drier weather in southeast Australia, above normal fire activity can be expected in the North West Pastoral, West Coast, Eastern Eyre Peninsula, Lower Eyre Peninsula, Flinders and Mid North districts (Bushfire and Natural Hazards CRC 2014).

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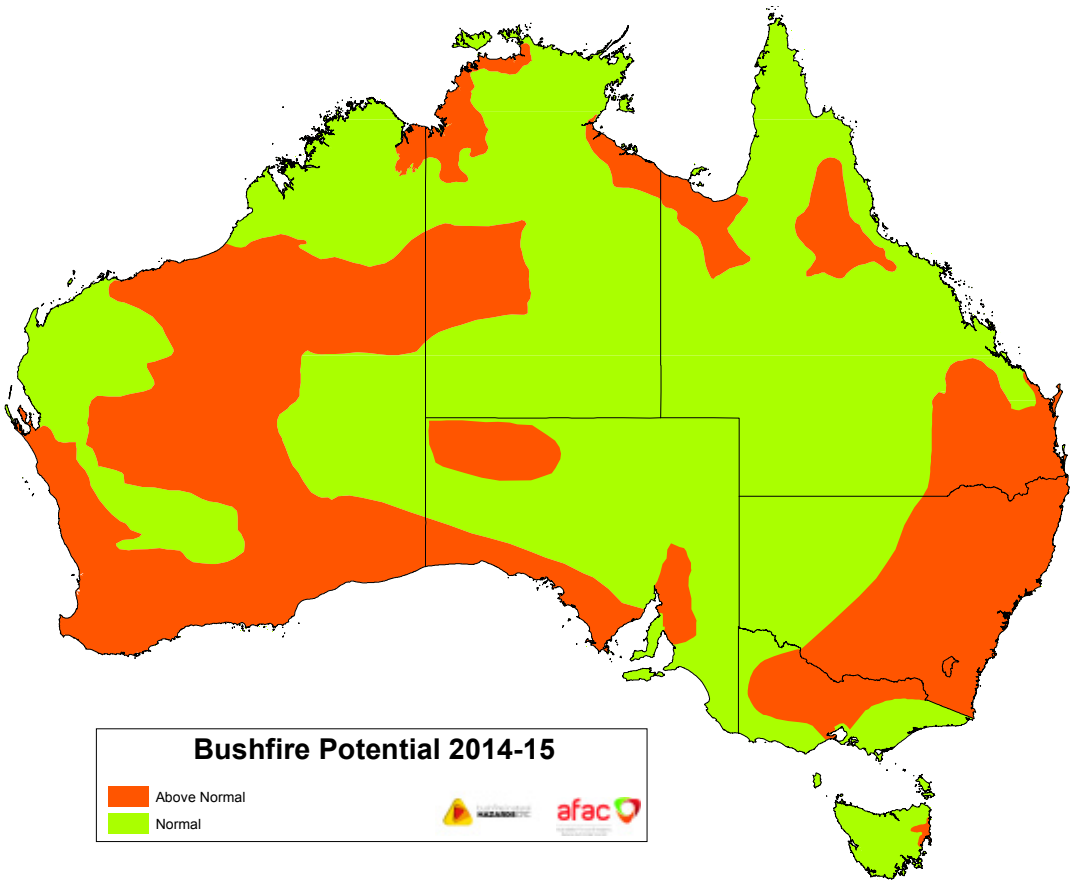

Figure 7: Australia Seasonal Bushfire Outlook (Bushfire and Natural Hazards CRC 2014)

Research aimed at understanding future fire activity in Australia's southeast has a long history (Table 1). While the detailed results of these studies vary due to the use of different global circulation models (GCMs) and different climate scenarios, their collective conclusion is clear – weather conditions conducive to fire in the southeast and southwest of the continent are becoming increasingly frequent and this trend will continue.

Future changes in the El Niño-Southern Oscillation (ENSO) phenomenon are also likely to have an influence on fire activity. There is a strong positive relationship between El Niño events and fire weather conditions in southeast and central Australia (Williams and Karoly 1999; Verdon et al. 2004; Lucas 2005) and between El Niño events and actual fire activity (Harris et al. 2013). Significant changes have occurred in the nature of ENSO since the 1970s, with the phenomenon being more active and intense during the 1979-2009 period than at any other time in the past 600 years (Aiken et al. 2013). Although there is no consensus on the influence of climate change on ENSO behaviour, recent projections suggest increases in El Niño-driven drying in the western Pacific Ocean by mid-to late 21st century (Power et al. 2013); such a change would increase the incidence of heat and drought, and potentially fire activity, in eastern Australia.

Table 1: Summary of projections from modeling studies aimed at projecting changes in fire risk in southeast Australia

Study	Projections
Beer et al. (1988)	10%-20% increase in FFDI in southeast.
Beer and Williams (1995)	Increase in FFDI with doubling of atmospheric CO_2, commonly >10% across most of continent, especially in the southeast, with a few small areas showing decreases.
Williams et al. (2001)	General trend towards decreasing frequency of low and moderate fire danger rating days, but an increasing frequency of very high and in some cases extreme fire danger days.
Lucas et al. (2007)	Increases in annual FFDI of up to 30% by 2050 over historical levels in southeast Australia and up to a trebling in the number of days per year where the uppermost values of the index are exceeded. The largest changes projected to occur in the arid and semi-arid interior of NSW and northern Victoria.
Hasson et al. (2009)	Analysed likelihood of increase in incidence of synoptic weather pattern in southeast Australia known to be associated with extreme fire events. Projected potential frequency of extreme events to increase from around 1 event every 2 years during the late 20th century to around 1 event per year in the middle of the 21st century, and to around 1 to 2 events per year by the end of the 21st century.
Clarke et al. (2011)	FFDI projected to decrease or show little change in the tropical northeast. In the southeast, FFDI projected to increase strongly by end of the 21st century, with the fire season extending in length and starting earlier.
Matthews et al. (2012)	Warming and drying climate projected to produce drier, more flammable fuel, and to increase rate of fire spread .

4. Impacts of bushfires in South Australia

Bushfires have had a very wide range of human and environmental impacts, including loss of life and severe health effects, damage to property, devastation of communities and effects on water and natural ecosystems (Stephenson 2010).

4.1 Health Impacts

Populations in South Australia are at risk from the health impacts of bushfires, which have contributed to physical and mental illness as well as death.

Tragically, in Australia bushfires have accounted for more than 800 deaths since 1850 (Cameron et al. 2009; King et al. 2013), and have contributed to numerous fatalities in South Australia. For example the Black Tuesday bushfires claimed the live of nine South Australian residents. In addition to fatalities, bushfire smoke can seriously affect health. Smoke contains not only respiratory irritants, but also inflammatory and cancer-causing chemicals (Bernstein and Rice 2013). Smoke can be transported in the atmosphere for hundreds or even thousands of kilometres from the fire front, exposing large populations to its impacts (Spracklen et al. 2009; Dennekamp and Abramson 2011; Bernstein and Rice 2013). For example, in 2006, air quality in Adelaide was rated as 'very poor' 3% of the year (this is equal to 12 days). These twelve days of poor air quality were attributed to smoke from bushfires or windblown dust (Dougherty 2006). The impacts of bushfire smoke in the community are also uneven, with the elderly, infants and those with chronic heart or lung diseases at higher risk (Morgan et al. 2010).

In addition to physical health impacts, the trauma and stress of experiencing a bushfire can also increase depression, anxiety, and other mental health issues, both in the immediate aftermath of the trauma and for months or years afterwards (McFarlane and Raphael 1984; Sim 2002; Whittaker et al. 2012). For example, in the aftermath of an event such as the Ash Wednesday fires it is expected that 20% of the affected population will develop significant psychological issues (McFarlane 1990). Post-traumatic stress, major depression, anxiety and suicide can also manifest among firefighters, sometimes only becoming evident many months after an extreme event (McFarlane 1988; Cook et al. 2013).

In the aftermath of an event such as the Ash Wednesday fires it has been estimated that 20% of the affected population will develop significant psychological issues.

4.2 Economic Costs

The economic cost of bushfires – including loss of life, livelihoods, property damage and emergency services responses– is very high. The total economic cost of bushfires, a measure that includes insured losses as well as broader social costs, is estimated to be $337 million per year in Australia (2011$), a figure that is expected to reach $800 million by around 2050 (Deloitte Access Economics 2014). The total economic costs of South Australian bushfires for 2014 are projected to be $44 million (2011$). By about mid century these costs will almost double, potentially reaching $79 million (Deloitte Access Economics 2014). These estimates take into account increases in the number of households, growth in the value of housing stock, population growth and increasing infrastructure density.

Figure 8: Bushfire damage, Flinders Chase National Park, Kangeroo Island

Bushfires can cause direct damage to properties, for example when the Ash Wednesday fires destroyed 2,400 homes in Victoria and South Australia (AEMI 2014). Indirect costs, such as impacts on local tourism industries can also be significant. For example, in New South Wales a month after the 2013 Blue Mountains bushfires, tourism operators estimated losses of nearly $30 million due to declines in visitors and cancellations alone (ABC 2013).

The Ash Wednesday fires destroyed 2,400 homes in Victoria and South Australia

Bushfires can cause significant losses in farming areas of regional and rural South Australia. Bushfires can cause the death of hundreds of thousands of livestock and affect significant amounts of farming land. For example the Black Tuesday fires of 2005 killed approximately 47,000 livestock (SACFS 2014a). Stock that survives the initial bushfires can face starvation in the post-fire period, as well as threats from predators due to the destruction of fences around properties (Stephenson 2010). The Black Tuesday fires destroyed approximately 6,300 kilometers of fencing (SACFS 2014a). Smoke damage can also taint fruit and vegetable crops, with wine grapes particularly susceptible, which is bad news for South Australia's strong wine industry (Stephenson 2010). The industry has been increasingly affected by bushfire smoke taint in wine, which can often make grapes unusable as they produce smoky, burnt ash aromas (Anderson et al. 2008).

It is important to note that these economic losses do not account for the full range of costs associated with bushfires – few attempts have been made to account for loss of life, social disruption and trauma, opportunity costs for volunteer fire fighters, fixed costs for bushfire fighting services, government contributions for rebuilding and compensation, impacts on health, and ecosystem services (King et al. 2013).

4.3 Environmental Impacts

Fire can affect the quality and quantity of water in catchments and have significant impacts on ecosystems.

4.3.1 Impact on water quality and quantity

Large-scale high intensity fires that remove vegetation expose topsoils to erosion and increased runoff after subsequent rainfall (Shakesby et al. 2007). This can increase sediment and nutrient concentrations in nearby waterways, potentially making water supplies unfit for human consumption (Smith et al. 2011; IPCC 2014). For example, bushfires in January 2003 devastated almost all of the Cotter catchment in the Australian Capital Territory, causing unprecedented levels or turbidity, iron and manganese and significantly disrupting water supply (White et al. 2006). Fires can also affect water infrastructure. Fires in the Sydney region in 2002 affected the Woronora pumping station and water filtration plants, resulting in a community alert to boil drinking water (WRF 2013). In South Australia a wildfire in 2007 burned a reservoir catchment that supplied water to Adelaide, negatively affecting the quality of the water (Smith et al. 2011).

4.3.2 Impact on ecosystems

Fire is a regular occurrence in many Australian ecosystems, and many species have evolved strategies over millions of years to not only withstand fire, but to benefit from it (Crisp et al. 2011, Bowman et al. 2012). Fire does not "destroy" bushland, as is often reported; rather, it acts as a major disturbance with a range of complex impacts on different species and communities. Particular fire regimes (especially specific combinations of fire frequency and intensity) can favour some species and disadvantage others. If fires are too frequent, plant species can become vulnerable to local extinction as the supply of seeds in the soil declines. Conversely, if the interval between fires is too long, plant species that rely on fire for reproduction may be eliminated from an ecological community. Animals are also affected by bushfires, for example if they are restricted to localised habitats and cannot move quickly, and/or reproduce slowly, they may be at risk from intense large-scale fires that occur at short intervals (Yates et al. 2008). For example, bushfires can be catastrophic for koalas, destroying eucalypt foliage, as well as burning and killing the iconic Australian marsupial. Major fires can also act as a barrier to koala dispersal, reducing the source of immigrants and leading to localised population declines (Matthews et al. 2007; Wallis 2013).

Figure 9: Tree-dwelling animals like koalas are very vulnerable during and immediately after bushfires.

5. Implications of increasing fire activity

The risk that bushfires pose to people are particularily acute in southern Australia, where large populations live close to highly flammable native vegetation that is exposed to frequent severe fire weather. The population of South Australia could potentially grow from 1.7 million (as of June 2012) to 2.6 million in 2061 (ABS 2014). In South Australia, 39 councils have designated bushfire protection areas within their council boundaries as numerous homes are within close proximity to bushland (SA government 2014). The increasing population and built assets, coupled with increasing fire danger weather, present significant and growing challenges for the state.

The economic, social and environmental costs of increasing bushfire activity in South Australia are potentially immense. As noted in Section 4.2, an analyses of projected costs of bushfires in South Australia by Deloitte Access Economics (2014) forecast that bushfires in South Australia could cost $79 million by about mid century (2011$), based only on population and asset increases, but not including increased risk due to climate change.

The economic, social and environmental costs of increasing bushfire activity in South Australia are potentially immense.

Figure 10: Bushfires in Clayton, South Australia

There is increasing interest in how adaptation to an increasingly bushfire-prone world may reduce vulnerability. Current initiatives centre on planning and regulations, building designs to reduce flammability, burying powerlines in high risk areas and retrofitting electricity systems, fuel management, fire detection and suppression, improved early warning systems, and community education (Preston et al. 2009; Buxton et al. 2011; O'Neill and Handmer 2012; King et al. 2013). Responses to bushfires can be controversial, particularly the practise of prescribed burning, where fires are lit in cool weather to reduce the volume of fuel. Fire managers are constantly faced with the challenge of balancing the need to reduce risk to life and property whilst simultaneously conserving biodiversity and environmental amenity, and controlling air pollution near urban areas (Penman et al. 2011; Williams and Bowman 2012; Adams 2013; Altangerel and Kull 2013). The increasing length of the fire season will reduce the window of opportunity for hazard reduction at the same time that the need for hazard reduction becomes greater.

Australia's premier fire and emergency services agencies have recognised the implications of climate change for bushfire risk and fire-fighting resources for some time

Australia's premier fire and emergency services agencies have recognised the implications of climate change for bushfire risk and fire-fighting resources for some time (AFAC 2009; 2010). Longer fire seasons have implications for the availability and costs of fire-fighting equipment that is leased from fire fighting agencies in the Northern Hemisphere. As fire seasons in the two hemispheres increasingly overlap, such arrangements may become increasingly impractical (Handmer et al. 2012).

Substantially increased resources for fire suppresson and control will be required. Among these resources are professional firefighters, the number of whom in Australia will need to grow by an estimated 20% (that is, by about 2300) by 2020 (compared to 2012) just to keep pace with increased population and asset growth (NIEIR 2013). When the increased incidence of fire-related extreme weather is also taken into account, the estimate is that a further 1200 fire fighters will be needed.

6. This is the Critical Decade

The impacts of climate change are already being observed. Sea levels are rising, oceans are becoming more acidic, and heatwaves have become longer and hotter. We are now more confident than ever that the emission of greenhouse gases by human activities, mainly carbon dioxide from the combustion of fossil fuels, is the primary cause for the changes in climate over the past half-century (IPCC 2013; 2014).

Projections of future climate change and its impacts have convinced nations that the global average temperature, now at 0.9°C above the pre-industrial level, must not be allowed to rise beyond 2°C– the so-called '2°C guardrail'. Societies will have to adapt to even more serious impacts as the temperature rises. For South Australia, these impacts include increased fire danger weather and longer bushfire seasons. Ensuring that this guardrail is not exceeded will prevent even worse impacts from occurring.

The evidence is clear and compelling. The trend of increasing global emissions must be halted within the next few years and emissions must be trending downwards by 2020. Investment in renewable, clean energy must therefore increase rapidly. And, critically, most of the known fossil fuel reserves must remain in the ground.

This is the critical decade to get on with the job.

References

ABC News (14 November 2013) Tourism losses hit $30m after Blue Mountains bushfires. Accessed at http://www.abc.net.au/news/2013-11-14/tourism-losses-hit-2430m-after-blue-mountains-bushfires/5090840.

Adams, M (2013) Mega-fires, tipping points and ecosystem services: managing forests and woodlands in an uncertain future. *Forest Ecology and Management* 294: 250-261.

AFAC (2009) *Climate Change and the Fire and Emergency Services Sector.* Position paper prepared for the Australasian Fire and Emergency Service Authorities Council. Accessed at http://www.afac.com.au/positions/Climate_Change_and_the_Fire_and_Emergency_Services_Sector.

AFAC (Australasian Fire and Emergency Services Council) (2010) *Climate Change and the Fire and Emergency Services Sector.* Discussion paper prepared for the Australasian Fire and Emergency Service Authorities Council. Accessed 10.11.13 at http://www.afac.com.au/positions/Climate_Change_and_the_Fire_and_Emergency_Services_Sector.

Aiken CM, Santoso A, McGregor S and England MH (2013) The 1970's shift in ENSO dynamics: A linear inverse model perspective. *Geophysical Research Letters* 40: 1612-1617.

Altangerel K, Kull CA (2013) The prescribed burning debate in Australia: conflicts and compatibilities. *Journal of Environmental Planning and Management* 56:103-120.

Anderson, K, Findlay C, Fuentes S and Tyerman S (2008) Viticulture, wine and climate change. *Garnaut Climate Change Review*. Accessed at http://www.garnautreview.org.au/CA25734E0016A131/WebObj/01-HViticulture/$File/01-H%20Viticulture.pdf.

ABS (Australian Bureau of Statistics) (2014) Population Projections, Australia, 2012 (base) to 2101. Accessed at http://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/3222.0Main%20Features102012%20(base)%20to%202101?opendocument&tabname=Summary&prodno=3222.0&issue=2012%20(base)%20to%202101&num=&view=.

Australian Emergency Management Institute (AEMI) (2014) Historical Disasters: Ash Wednesday. Australian Government. Accessed at http://www.em.gov.au/library/Onlineresources/Historicaldisasters/Pages/HistoricalDisastersAshWednesday.aspx.

Australian Emergency Management (AEM) (2014a) Bushfire: Ash Wednesday, Victoria and South Australia 1983. Accessed at https://www.emknowledge.gov.au/resource/?id=131.

Australian Emergency Management (AEM) (2014b) Bushfire: Eyre Peninsula, South Australia 2005. Accessed at https://www.emknowledge.gov.au/resource/?id=378.

Beer T, Gill AM and Moore RHR (1988) Australian bushfire danger under changing climatic regimes. In Pearman GI (ed.), *Greenhouse: Planning for Climatic Change* 29:169-188.

Beer T, Williams A (1995) Estimating Australian forest fire danger under conditions of doubled carbon dioxide concentrations. *Climatic Change* 29: 169-188.

Bernstein AS and Rice MB (2013) Lungs in a warming world: climate change and respiratory health. *CHEST Journal* 143:1455-59.

BoM (Bureau of Meteorology) (2013) Australian climate variability and change—Time series: Annual mean temperature anomaly—Australia (1910-2012). Accessed at http://www.bom.gov.au/climate/change/index.shtml#tabs=Tracker&tracker=timeseries.

BoM (2014) Annual climate statement 2013 (issued Friday 3 January 2014). Accessed at http://www.bom.gov.au/climate/current/annual/aus/2013.

Bowman DMJS, Murphy BP, Burrows GE and Crisp MD (2012) Fire regimes and the evolution of the Austrlaian biota. In *Flammable Australia: Fire regimes, biodiversity and ecosystems in a changing world.* Bradstock RA, Gill AM, Williams RJ (eds), CSIRO Publishing, Collingwood, VIC, pp 27-48.

Bradstock RA (2008) Effects of large fires on biodiversity in south-eastern Australia: disaster or template for diversity? *International Journal of Wildland Fire* 17:809-822.

Bradstock RA, Cohn JS, Gill AM, Bedward M and Lucas C (2009) Prediction of the probability of large fires in the Sydney region of south-eastern Australia using fire weather. *International Journal of Wildland Fire* 18: 932-943.

Bradstock RA, Boer MM, Cary GJ, Price OF, Williams RJ, Barrett D, Cook G, Gill AM, Hutley LBW, Keith H, Maier SW, Meyer M, Roxburgh SH and Russell-Smith J (2012) Modelling the potential for prescribed burning to mitigate carbon emissions from wildfires in fire-prone forests of Australia. *International Journal of Wildland Fire* 21:629-639.

Bradstock RA and Price O (2013) Modelling the implications of ignition in the Sydney Basin, Australia: implications for future management. *International Journal of Wildland Fire* 22: 469-478.

Bushfires and Natural Hazards Cooperative Research Centre (Bushfire and Natural Hazards CRC) (2014) Southern Australia Seasonal Bushfire Outlook 2014-15. Accessed at http://www.bnhcrc.com.au/news/2014/southern-australia-seasonal-bushfire-outlook-2014-15.

Buxton M, Haynes R, Mercer D and Butt A (2011) Vulnerability to bushfire risk at Melbourne's urban fringe: The failure of regulatory land use planning. *Geographical* Research 49: 1-12.

Cameron PA, Mitra B, Fitzgerald M, Scheinkestel CD, Stripp A, Batey C, Niggemeyer L, Truesdale M, Holman P, Mehra R, Wasiak J and Cleland H (2009) Black Saturday: the immediate impact of the February 2009 bushfires in Victoria, Australia. *Medical Journal of Australia* 191: 11-16.

Cary GJ, Bradstock RA, Gill AM and Williams RJ (2012) Global change and fire regimes in Australia pp149-170 in Flammable Australia: Fire regimes, biodiversity and ecosystems in a changing world. (Eds Bradstock RA, Gill AM, Williams RJ). CSIRO Publishing, Collingwood, VIC.

Clarke H, Smith PL and Pitman AJ (2011) Regional signatures of future fire weather over eastern Australia from global climate models. *International Journal of Wildland Fire* 20: 550-562.

Clarke H, Lucas C and Smith P (2013) Changes in Australian fire weather between 1973 and 2010. *International Journal of Climatology* 33: 931-944.

Climate Commission (2013) The Critical Decade: Extreme Weather. Hughes L, Steffen W.

Climate Council (2014a) Be Prepared: climate change and the Australian bushfire threat. Hughes L.

Climate Council (2014b) Heatwaves: hotter, longer, more often. Steffen W, Hughes L and Perkins S.

Cook B, Mitchell W (2013) Occupational health effects for firefighters: the extent an implications of physical and psychological injuries. *Report prepared for the United Firefighters Union of Australia,* Centre of Full Employment and Equity. Accessed https://www.firecrisis.com.au/wp-content/uploads/2013/02/cofFEE-report-Final.pdf.

Crisp MD, Burrows GE, Cook LG, Thornhill AH and Bowman DMJS (2011) Flammable biomes dominated by eucalypts originated at the Cretaceous-Palaeogene boundary. *Nature Communications* 2: 1-8.

CSIRO and BoM (2014) State of the Climate 2014. CSIRO and Bureau of Meteorology, Melbourne.

Deloitte Access Economics (2014) Scoping study on a cost benefit analysis of bushfire mitigation. Australia Forest Products Association. Accessed at http://www.ausfpa.com.au/wp-content/uploads/AFPA-DAE-report-Amended-Final-2014-05-27.pdf

Dennekamp M and Abramson MJ (2011) The effects of bushfire smoke on respiratory health. *Respirology* 16: 198-209.

Dougherty G (2006) South Australia's Air Quality 2006. Environmental Protection Agency. Accessed at http://www.epa.sa.gov.au/xstd_files/Air/Report/air_quality_2006.pdf.

Handmer J, McKellar R, McLennan B, Whittaker J, Towers B, Duggie J and Woolf M (2012) *National Climate Change Adaptation Research Plan: Emergency Management – Revised 2012 Edition*, National Climate Change Adaptation Research Facility, Gold Coast, 60pp.

Harris S, Nicholls N and Tapper N (2013) Forecasting fire activity in Victoria, Australia, using antecedent climate variables and ENSO indices. *International Journal of Wildland Fire* http://dx.doi.org/10.1071/WF13024.

Hasson AEA, Mills GA, Timbal B and Walsh K (2009) Assessing the impact of climate change on extreme fire weather even over southeastern Australia. *Climate Research* 39: 159-172.

IPCC (Intergovernmental Panel on Climate Change) (2012) *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.* A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Field CB, Barros V, Stocker TF, Qin D, Dokken DJ, Ebi KL, Mastrandrea.

IPCC (2013) *Climate Change 2013: The Physical Science Basis*. Working Group I Contribution to the IPCC 5th Assessment Report - Changes to the underlying Scientific/Technical Assessment. Accessed at http://www.ipcc.ch/report/ar5/wg1/.

IPCC (2014) *Climate Change 2014:Impacts, adaptation, and vulnerability.* Working Group II Contribution to the IPCC 5th Assessment Report. Chapter 25: Australasia. Accessed at http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Chap25_FGDall.pdf.

Jayaratne R and Kuleshov E (2006) The relationship between lightning activity and surface wet bulb temperature and its variation with latitude in Australia. *Meteorology and Atmospheric Physics* 91:17-24.

King D, Ginger J, Williams S, Cottrell A, Gurtner Y, Leitch C, Henderson D, Jayasinghe N, Kim P, Booth K, Ewin C, Innes K, Jacobs K, Jago-Bassingthwaighte M and Jackson L. (2013) *Planning, building and insuring: Adaptation of built environment to climate change induced increased intensity of natural hazards.* National Climate Change Adaptation Research Facility, Gold Coast, 361 pp.

Lucas C (2005) *Fire weather history of south-east Australia.* (Bushfire CRC) Accessed at http://www.bushfirecrc.com/managed/resource/fireweatherhistory.pdf.

Lucas C, Hennessy K, Mills G and Bathols J (2007). *Bushfire weather in southeast Australia: recent trends and projected climate change impacts*. Bushfire CRC and Australian Bureau of Meteorology. September 2007, Consultancy Report prepared for the Climate Institute of Australia.

Luke RH and McArthur AG (1978) *Bushfires in Australia.* Australian Government Publishing Service, Canberra.

Matthews A, Lunney D, Gresser S and Matiz W (2007) Tree use by koalas (phascolarctos cinereus) after fire in remnant coastal forest. *Wildlife Research*. 34: 84-93.

Matthews S, Sullivan AL, Watson P and Williams RJ (2012) Climate Change, fuel and fire behaviour in a eucalypt forest. *Global Change Biology* 18: 3212-3223.

McFarlane AC and Raphael B (1984) Ash Wednesday: the effect of a fire. Australian and New Zealand Journal of Psychiatry 18: 341–51.

McFarlane AC (1988) The longitudinal course of post-traumatic morbidity: the range of outcomes and their predictors. *Journal of Nervous and Mental Diseases* 176: 30–9.

McFarlane AC (1990) An Australian Disaster: the 1983 Bushfires. *International Journal of Mental Health* 19(2): 36-47.

Morgan G, Sheppeard V, Khalaj B, Ayyar A, Lincoln D, Jalaludin B, Corbett S and Lumely T. (2010) The effects of bushfire smoke on daily mortality and hospital admissions in Sydney, Australia, 1994 to 2002. *Epidemiology* 21: 47-55.

NIEIR (2013) *Firefighters and climate change: The human resources dimension of adapting to climate change*. Final and consolidated report prepared by the National Institute of Economic and Industry Research for the United Firefighters Union of Australia. Submission to the Senate Standing Committee on Environment and Communications Inquiry into trends and preparedness for extreme weather events. February 2013.

O'Neill SJ and Handmer J (2012) Responding to bushfire risk: the need for transformative adaptation. *Environmental Research Letters* 7: 014018.

Penman TD, Christie FJ, Andersen AN, Bradstock RA, Cary GJ, Henderson MK, Price O, Tran C, Wardle GM, Williams RJ andYork A (2011) Prescribed burning: how can it work to conserve the things we value? *International Journal of Wildland Fire* 20:721-733.

Power S, Delage F, Chung C, Kociuba G and Keay K (2013) Robust twenty-first-century projections of El Niño and related precipitation variability. *Nature* 502: 541-545.

Preston B, Brooke C, Measham T, Smith T and Gorddard R (2009) Igniting change in local government: lessons learned from a bushfire vulnerability assessment. *Mitigation and Adaptation Strategies for Global Change* 14: 251-283.

Shakesby RA, Wallbrink PJ, Doerr SH, English PM, Chafer CJ, Humphreys GS, Blake WH and Tomkins KM (2007) Distinctiveness of wildfire effects on soil erosion in south-east Australian eucalypt forests assessed in a global context. *Forest Ecology and Management* 238: 347-364.

Sim, M (2002) Bushfires: are we doing enough to reduce the human impact? *Occupational and Environmental Medicine* 59: 215-216.

South Australia Government (SA Government) (2014) About bushfire protection areas. Accessed at https://www.sa.gov.au/topics/housing-property-and-land/building-and-development/residential-building-regulations/fire-safety-and-bushfire-regulations/bushfire-protection-areas/about-bushfire-protection-areas.

Smith HG, Sheridan G, Lane PNJ, Nyman P and Haydon S (2011) Wildfire effects on water quality in forest catchments: A review with implications for water supply. *Journal of Hydrology* 396: 170-192.

SACFS (South Australian Country Fire Service) (2014a) Bushfire History. Accessed at http://www.cfs.sa.gov.au/site/about/history/bushfire_history.jsp.

SACFS (2014b) Fire Ban & Danger Rating Advice for 22 October 2014. Accessed at http://www.cfs.sa.gov.au/site/homes/criimson/cfs_fire_ban_and_fire_danger_rating_issued_21_oct_1656.jsp.

Spracklen DV, Mickley LJ, Logan JA, Hudman RC, Yevich R, Flannigan MD and Westerling AL (2009) Impacts of climate change from 2000 to 2050 on wildfire activity and carbonaceous aerosol concentrations in the western United States. *Journal of Geophysical Research* 114: D20301.

Stephenson C (2010) A literature review on the economic, social and environmental impacts of severe bushfires in south-eastern Australia. *Fire and Adaptive Management Report No. 87*. Bushfire CRC.

Timbal B and Drosdowsky W (2012). The relationship between the decline of south eastern Australia rainfall and the strengthening of the sub tropical ridge. International Journal of Climatology 33(4): 1021-1034.

Trenberth KE (2012) Framing the way to relate climate extremes to climate change. *Climatic Change* 115: 283-290.

Verdon DC, Kiem AS and Franks SW (2004) Multi-decadal variability of forest fire risk – eastern Australia. *International Journal of Wildfire Fire* 13: 165–171.

Wallis RL (2013). Koalas Phascolarctos cinerteus in Framlingham Forest, south-west Victoria: introduction, translocation and the effects of a bushfire. *Victorian Naturalist* 130 (1): 37-40. http://search.informit.com.au.ezproxy1.library.usyd.edu.au/documentSummary;dn=260156100721864;res=IELHSS.

Western Australian Land Information Authority (2013) Landgate FireWatch. Accessed at http://firewatch.landgate.wa.gov.au/landgate_firewatch_public.asp.

White I, Wade A, Worthy M, Mueller N, Daniel T, Wasson R (2006) The vulnerability of water supply catchments to bushfires: impacts of the January 2003 wildfires on the Australian Capital Territory. *Australian Journal of Water Resources* 10:1-16.

Whittaker J, Handmer J and Mercer D (2012) Vulnerability to bushfires in rural Australia: A case study from East Gippsland, Victoria. *Journal of Rural Studies* 28: 161-73.

Williams AAJ and Karoly DJ (1999) Extreme fire weather in Australia and the impact of the El Niño–Southern Oscillation. *Australian Meteorological Magazine* 48: 15–22.

Williams AAJ, Karoly DJ and Tapper N (2001) The sensitivity of Australian fire danger to climate change. *Climactic Change* 49: 171-191.

Williams RJ, Bradstock RA, Cary GJ, Enright NJ, Gill AM, Liedloff AC, Lucas C, Whelan RJ, Andersen AN, Bowman DMJS, Cook GD, Hennessy KJ and York A. (2009) *Interactions between climate change, fire regimes and biodiversity in Australia – a preliminary assessment.* Report to the Department of Climate Change and Department of the Environment, Water, Heritage and the Arts, Canberra. 214 p.

Williams RJ and Bowman DMJS (2012) Fire futures for a megadiverse continent. *New Phytologist* 196: 337-340.

Willis M (2005) Bushfire arson: a review of the literature. *Research and Public Policy Series No. 61*. Bushfire CRC, Melbourne. 166 pp.

WRF (Water Research Foundation) (2013) Water quality impacts of extreme weather events. Water Research Foundation, Denver, Colorado

Yates CP, Edwards AC and Russell-Smith J (2008) Big fires and their ecological impacts in Australian savannas: size and frequency matters. *International Journal of Wildland Fire* 17: 768–781.

IMAGE CREDITS

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Preparing for a Bushfire in South Australia

IN AN EMERGENCY, CALL TRIPLE ZERO (106 FOR PEOPLE WITH A HEARING OR SPEECH IMPAIRMENT) 000

What can I do to prepare for a bushfire?

INFORM YOURSELF

The South Australian Country Fire Service has the resources available to help you prepare for a bushfire. Use these resources to inform yourself and your family.

ASSESS YOUR LEVEL OF RISK

The excellent resources of the South Australian Country Fire Service are available to assist you to assess your level of risk from bushfire. Take advantage of them. Visit: http://www.cfs.sa.gov.au/site/prepare_for_bushfire/know_your_risk.jsp

MAKE A BUSHFIRE SURVIVAL PLAN

Even if your household is not at high risk from bushfire (such as suburbs over 1 km from bushland), you should still educate yourself about bushfires, and take steps to protect yourself and your property. Access the bushfire ready self assessment tool: http://www.cfs.sa.gov.au/site/prepare_for_bushfire/be_bushfire_ready/be_bushfire_ready_app.jsp

PREPARE YOUR PROPERTY

Regardless of whether you decide to leave early or to stay and actively defend, you need to prepare your property for bushfire, An important consideration is retrofitting older houses to bring them in alignment with current building codes for fire risk and assessing the flammability of your garden. Use the CFS Bushfire Ready Assessment Tool to help recognise exactly what you need to prepare your property: http://www.cfs.sa.gov.au/site/prepare_for_bushfire/be_bushfire_ready/be_bushfire_ready_app.jsp

PREPARE YOURSELF AND YOUR FAMILY

Preparation is not only about the physical steps you take to prepare – e.g., preparing your house and making a bushfire survival plan. Preparing yourself and your family also involves considering your physical, mental and emotional preparedness for a bushfire and its effects. Take the time to talk to your family and to thoroughly prepare yourself on all levels.

Key Links

SA RFS:
http://www.cfs.sa.gov.au/site/prepare_for_bushfire.jsp

1300 362 361

Bushfire Self Assessment Tool:
http://www.cfs.sa.gov.au/site/prepare_for_bushfire/be_bushfire_ready/be_bushfire_ready_app.jsp

Fire Watch Map:
http://myfirewatch.landgate.wa.gov.au/