CLIMATE COMMISSION

The Angry Summer

Key facts

1. Extreme weather events dominated the 2012/2013 Australian summer, including record-breaking heat, severe bushfires, extreme rainfall and damaging flooding. Extreme heatwaves and catastrophic bushfire conditions during the Angry Summer were made worse by climate change.
2. All weather, including extreme weather events, is influenced by climate change. All extreme weather events are now occurring in a climate system that is warmer and moister than it was 50 years ago. This influences the nature, impact and intensity of extreme weather events.
3. Australia's Angry Summer shows that climate change is already adversely affecting Australians. The significant impacts of extreme weather on people, property, communities and the environment highlight the serious consequences of failing to adequately address climate change.
4. It is highly likely that extreme hot weather will become even more frequent and severe in Australia and around the globe over the coming decades. The decisions we make this decade will largely determine the severity of climate change and its influence on extreme events for our grandchildren.
5. It is critical that we are aware of the influence of climate change on many types of extreme weather so that communities, emergency services and governments prepare for the risk of increasingly severe and frequent extreme weather.

The Climate Commission has received questions from the community and the media seeking to understand the influence of climate change on the extreme summer weather. This report provides a summary of the extreme weather of the 2012/2013 summer and the influence of climate change on such events.

Extreme weather events and climate change

The Angry Summer of 2012/13

Over the summer of 2012/2013 Australia was hit by a series of extreme weather events, including heatwaves, bushfires, intense rainfall and flooding, that caused serious damage in many places (Figure 1; Figure 2).

A blistering heatwave, unusual in the vast area it covered and its long duration, affected 70% of Australia in late December and early January (BoM, 2013a). Temperature records were broken right across Australia, from Hobart, to Birdsville, to Blacktown, to Adelaide and Perth.

The heatwave brought catastrophic bushfire conditions to many areas across Australia. For example, in New South Wales catastrophic fire warnings were declared in the Shoalhaven, the Illawarra, the Southern Ranges, the Northern and Eastern Riverina and southern parts of the Lower Central West Plains in early January 2013. Major bushfires raged in Tasmania, New South Wales and Victoria.

Later in January, extreme rainfall fell over the east coast of Queensland and the New South Wales coast north of the Illawarra, resulting in severe flooding and damage (BoM, 2013b).

The extreme weather continued through February. An intense low pressure system moved along the east coast of New South Wales, leading to flooding and wind damage in places along the coast. At the time of writing tropical cyclone Rusty was threatening the Pilbara coast of northwest Western Australia with high winds, heavy rainfall and a large storm surge. Rusty was a category-4 storm with winds of 230km/h near the storm centre (BoM, 2013c).

Over the Angry Summer numerous heat, rainfall and flood records were broken across Australia.

The summer of 2012/2013 was Australia's hottest summer since records began in 1910.

Key facts:

- The hottest ever area-averaged Australian maximum temperature occurred on 7 January, reaching 40.30 °C
- 44 weather stations had all-time high maximum temperatures, including Sydney, Hobart and Newcastle
- There have only been 21 days in 102 years where the average maximum temperature for the whole of Australia has exceeded 39 °C; eight of these days happened this summer (2–8 January and 11 January 2013)

(BoM, 2013a)

As this report was being written, some fires continued to rage and a number of communities continued to suffer from flooding. The clean-up in many parts of Australia is only just underway and the toll of the summer disasters is yet to be determined. Many Australians are suffering from the damage of extreme weather again, after the severe flooding of 2010/2012. As a result, the resources required for our society to deal with extreme weather is increasing.

Understanding the influence of climate change on extreme weather

Australia has always been, and will continue to be, a land of extremes. As Dorothea Mackellar wrote, Australia is a land of 'droughts and flooding rains'. However, climate change is now making many types of extreme weather worse, especially weather related to higher temperatures. The record-breaking events of the Angry Summer show that climate change is already affecting Australians.

It is crucial that we are aware of the influence of climate change on extreme weather so that communities, emergency services, health services and other authorities are prepared for the likelihood of increasingly severe and frequent extreme weather.

The basic features of the climate system have now shifted and are continuing to shift, changing the conditions for all weather, including extreme events. The Earth has warmed by 0.8 °C over the last 100 years. This has led to increased air and sea surface temperatures, rising sea level and more moisture in the atmosphere.

In summary, there is now an ongoing fundamental shift in the climate system.

All of the extreme weather events of the Angry Summer occurred in a climate system that contains vastly more heat compared to 50 years ago (Trenberth, 2012). That means that they were all influenced to some extent by a climate that is fundamentally shifting.

- Climate change has made the extreme heat conditions worse, with the length, extent and severity of the January heatwave unprecedented since records began
- Climate change aggravated bushfire conditions across southern Australia
- The extreme rainfall experienced on the Australian east coast has been influenced by the shifting climate, although determining the nature of that influence is more complex than for temperature-related extreme events.

The record-breaking heat of the Angry Summer was unusual because it occurred in the absence of an El Niño event, a 12–18 month period of warm, dry conditions that push up observed temperatures. Prior to 2012/2013, six of the eight hottest Australian summers on record, and the three hottest, occurred in El Niño years. The extreme temperatures of the Angry Summer occurred without the push of an El Niño.

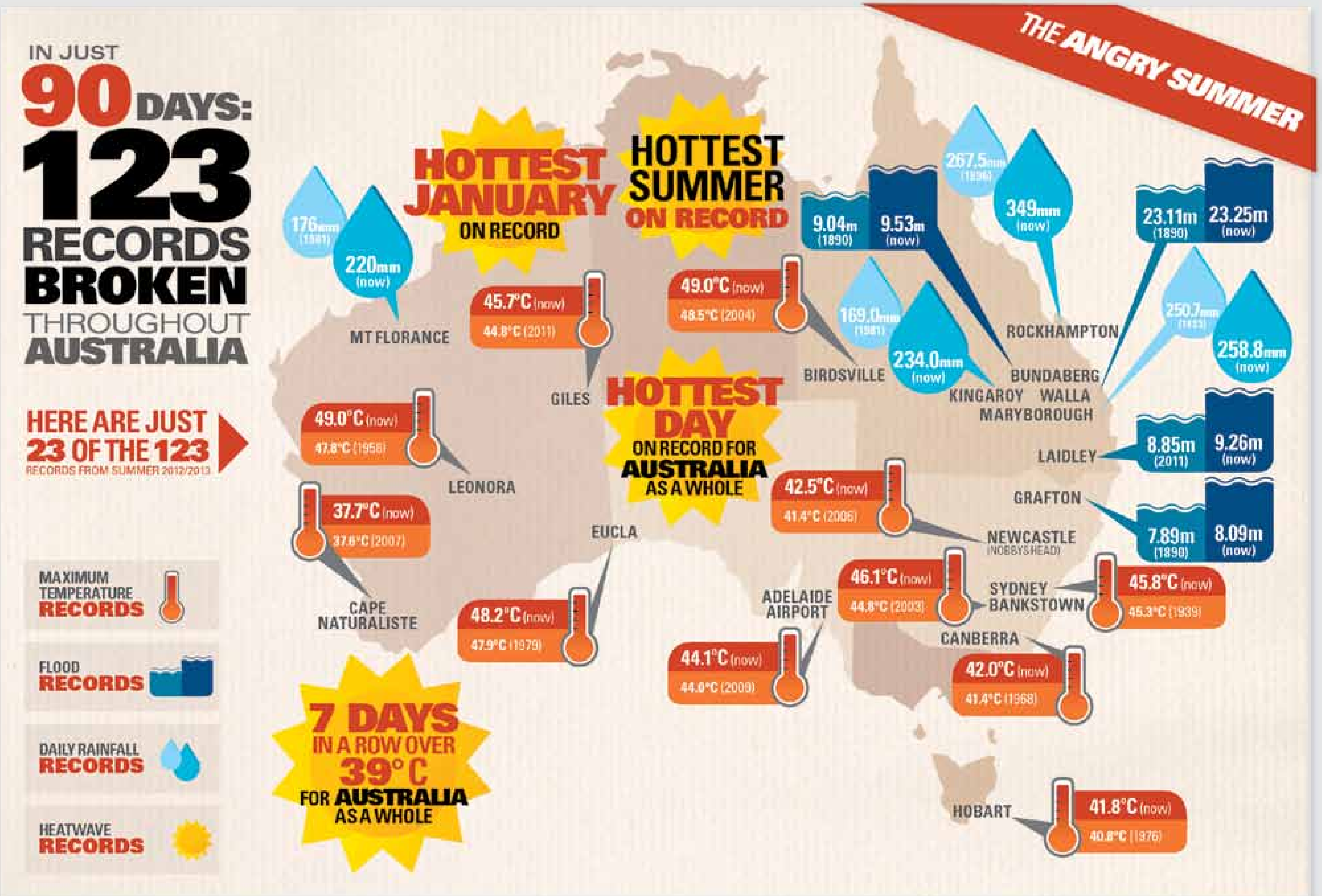
The future for extreme weather in Australia

Looking towards the future, it is virtually certain that extreme hot weather will continue to become even more frequent and severe around the globe, including Australia, over the coming decades. It is also likely that the frequency of heavy rainfall will increase over many areas of the globe (IPCC, 2012).

The preventative actions we take now and in the coming years will greatly influence the extent of climate change and therefore the severity of extreme events that our children, and especially our grandchildren, will experience.

In Australia and around the world we need to urgently invest in clean energy sources and take other measures to reduce emissions of greenhouse gases. This is the critical decade to get on with the job.

Figure 1: During the summer of 2012/2013 a series of extreme events hit the nation.



Data sources: BoM, 2013a,b

Figure 2: Summary of the extreme weather events of the Angry Summer.

Data sources: BoM, 2013a,b,c,d,f,h; RFS, 2013a,b

The Angry Summer in detail

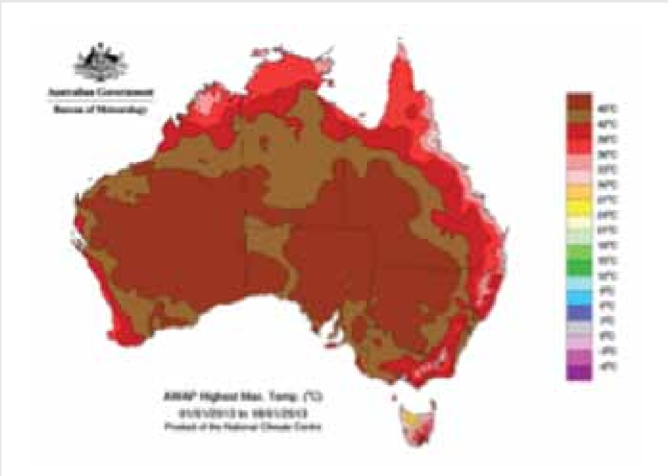
Heatwaves

Prolonged periods of high temperatures affect human health, animals and ecosystems, critical infrastructure and agricultural productivity. Heat kills more Australians than any other extreme weather event (PwC, 2011).

What happened?

The heatwave in late December 2012 and the first weeks of January 2013 were unusually long and widespread. Over 70% of Australia experienced extreme temperatures at some stage during the heatwave, with the most extreme and long-lasting heat occurring in the central and southern interior of the continent (Figure 3; BoM, 2013a).

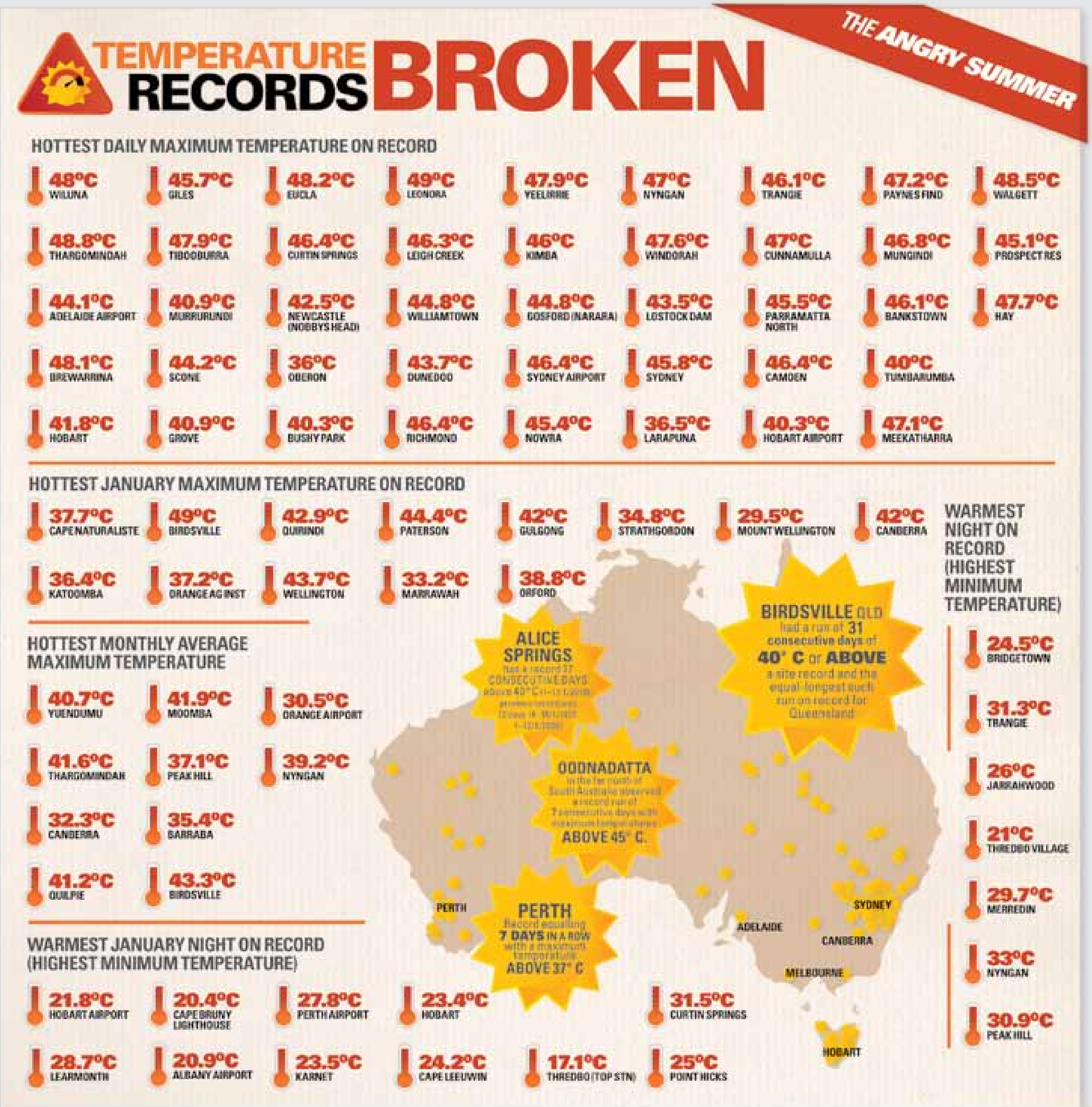
Figure 3: Highest maximum temperature reported in the period 1 January 2012 – 18 January 2013.



Source: BoM, 2013a

The 2012/2013 summer was the hottest on record. Temperature records were set in every state and territory (Figure 4) and the national average daily temperature rose to levels never previously observed. Based on the network of long-term, high quality stations, no previous event has resulted in so many temperature records (BoM, 2012; BoM, 2013a).

Figure 4: The individual site temperature records that were broken during the Angry Summer.



Data source: BoM, 2013a

The length, extent and severity of this heatwave are unprecedented since records began.

- For seven days running, from 2–8 January 2013, the average daily maximum temperature for the whole of Australia was over 39 °C, easily breaking the previous record of four consecutive days over 39 °C.
- This is the longest period ever for such persistently high temperatures.
- In fact, there have only been 21 days in 102 years where the average maximum temperature across Australia has exceeded 39 °C; eight of these days happened this summer (2–8 January and 11 January 2013).

(BoM, 2013a)

The extreme heat followed an unusually very warm and dry period at the end of 2012, with below-average rainfall across much of Australia and a notably late start to the monsoon period (BoM, 2013a). The September-December 2012 period was the hottest ever. The average Australian maximum temperature was higher than for any other September-December period since records began in 1910.

Since mid-2012 much of Australia was drier than usual. The build-up of extreme heat in the southwest of Western Australia signalled the beginning of the first heatwave (Figure 5). Perth experienced seven consecutive days above 37 °C from 25–31 December, equalling a previous record (BoM, 2013a). Then a second heatwave brought record breaking heat on 8-10 January 2013. The central and southern interior suffered particularly extreme conditions, with Leonora recording the highest temperature in Western Australia during this event (BoM, 2013a).

How does climate change influence heatwaves and hot days?

While hot weather has always been common in Australia, it has become more common and severe over the past few decades. Australia's average temperature has risen by 0.9 °C since 1910 (CSIRO and BoM, 2007), consistent with the global trend of increasing average temperature.

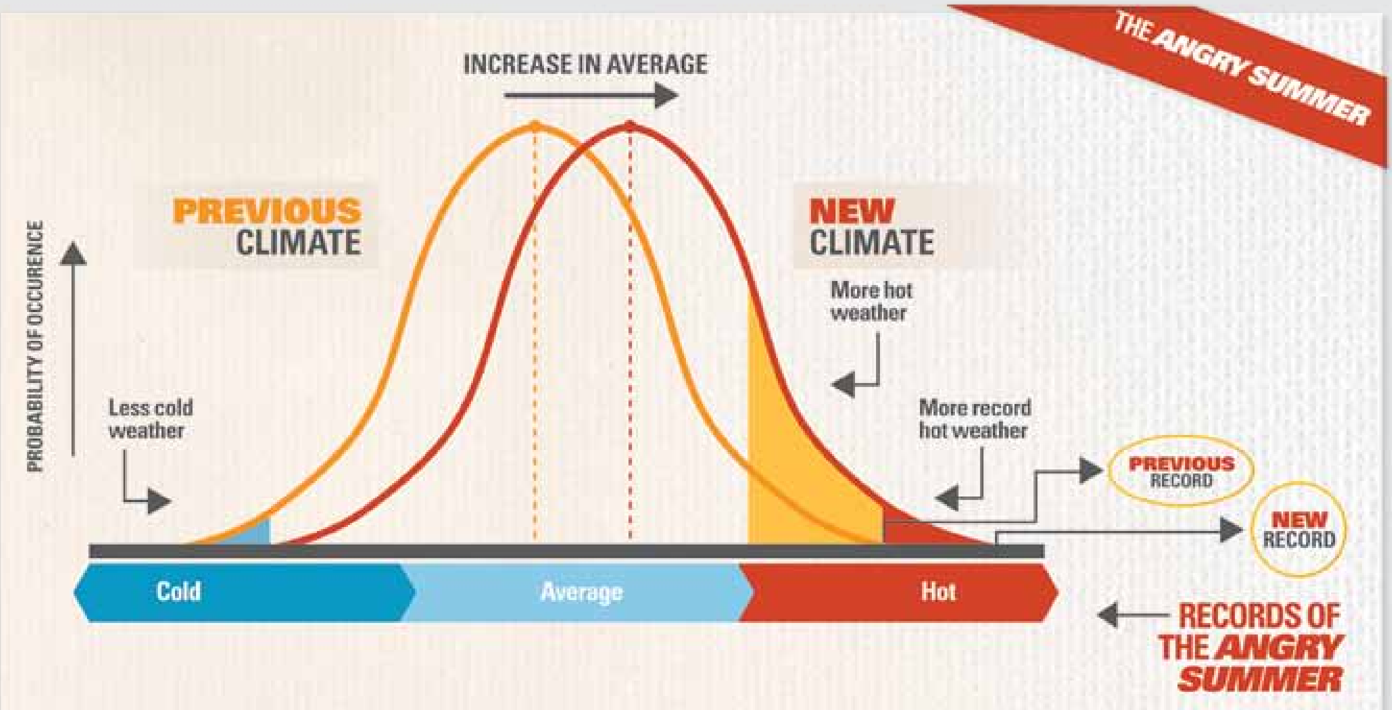
Such a seemingly modest increase of 0.9 °C in average temperature can have a surprisingly large impact on the frequency and nature of temperature-related extreme weather events. When the average temperature shifts, the temperatures at the hot and cold ends (tails) of the temperature range shift too (Figure 6). A small increase in the average temperature creates a much greater likelihood of very hot weather and a much lower likelihood of very cold weather.

Figure 5: Western Australian summer – timeline of events late 2012 to early 2013.

Data source: BoM, 2013a

Figure 6 demonstrates the shift to a 'new climate'. The shaded area under the curve shows the increasing likelihood of more hot weather and more record hot weather, while there is less cold weather. The heavy shaded area at the extreme right shows the record hot weather that occurs only under the new climate. From these basic statistics, we can expect more record hot weather and less record cold weather as the climate warms (IPCC, 2007).

Figure 6: Relationship between average and extremes, showing the connection between a shifting average and the proportion of extreme events.



Source: modified from IPCC, 2007

Record hot weather has become more frequent, as expected (Figure 6; IPCC, 2007):

- The number of record hot days across Australia has doubled since 1960 with an average temperature increase of 0.9 °C. Correspondingly the number of record cold days has decreased (CSIRO and BoM, 2012)
- Over the last decade, record hot days occurred three times more often than record cold days (Trewin and Smalley, 2013)

There has also been a significant increase in the frequency of days over 35 °C over the last 50 years (CSIRO and BoM, 2012). For example, for Canberra the long-term average (1961–1990) number of days per year above 35 °C was 5.2, but during the decade 2000–2009 the average number of such days rose to 9.4 (BoM, 2013e). Although Australia has always had heatwaves and hot days, climate change has increased the likelihood of more intense heatwaves and hot days. In summary, climate change is making hot days and heatwaves worse.

Bushfires

Bushfires are a natural part of the Australian landscape; however, they can severely affect biodiversity, human health, property, economic activity and infrastructure.

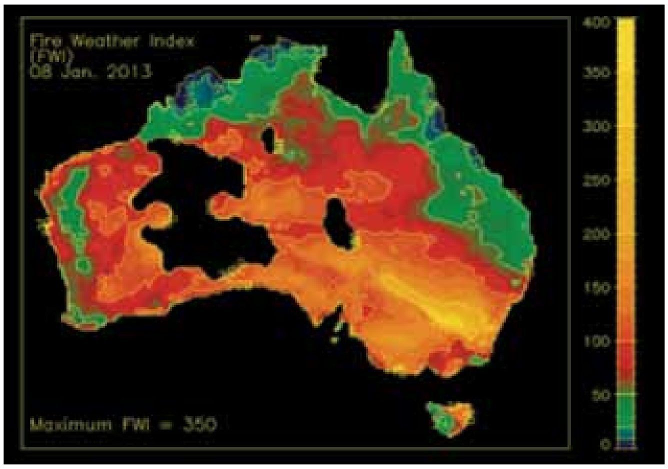
What happened?

In the first weeks of January, dangerous bushfire conditions occurred in many areas across Australia with major bushfires flaring in Tasmania, New South Wales and Victoria. For example, on 4 January 2013 up to 40 bushfires ignited across Tasmania under severe to extreme fire danger conditions (BoM, 2013f). The fire at Forcett, on the Tasman Peninsula, was the most damaging (BoM, 2013f; Figure 7). It swept into the town of Dunalley, destroying the local primary school, RSL club, service station and many homes. Overall, the Forcett fire burnt 25,000 hectares, destroyed close to 200 properties and 21 businesses and caused the evacuation of hundreds of people from the Tasman Peninsula (BoM, 2013f).

Figure 7: Fires at Forcett and Cropping, Tasmania on 4 January 2013.

Source: Chuq/Wikimedia

Figure 8: The Fire Weather Index (FWI) across Australia for 8 January 2013. Source: Centre for Australian Weather and Climate Research.



Source: CSIRO, 2013

Extreme and catastrophic bushfire conditions were declared across many areas in southeast Australia on 8 January 2013. The Fire Weather Index (FWI), a weather-based rating system for dangerous fire conditions, showed extremely dangerous conditions for large sections of NSW stretching from near the south coast north-westwards towards the South Australian border (Figure 8). Virtually all of the rest of the populous southeast corner of the continent recorded very high values of the FWI and thus experienced very dangerous fire conditions.

How does climate change influence bushfires?

The south of Australia is an extremely fire-prone region during the summer months. While many factors influence the potential for bushfires, the conditions conducive to fire outbreak and spread are highly sensitive to changes in climate and weather (Clarke et al., 2012). Hotter temperatures, longer duration of heat events, high winds and drier soils and fuel can dramatically exacerbate fire conditions. When a fire occurs in more extreme weather conditions, it is likely to become more intense and difficult to control.

The Forest Fire Danger Index (FFDI), used to gauge bushfire threat for forested areas, is a combination of air temperature, humidity, wind speed and drought (BoM, 2013g). The FFDI is scaled from 1 to 100, with 100 set for the very extreme weather conditions of the massive bushfires in 1939. The 'Severe' fire danger rating refers to an FFDI value between 50 and 74, and an 'Extreme' rating has a value between 75 and 99. A new 'Catastrophic' fire danger rating of 100 and above was introduced following the Black Saturday fires in 2009. The upwards extension of the FFDI reflects the record extreme weather conditions that are now occurring more frequently (RFS, 2009).

Many regions including Perth, Adelaide and Melbourne have already experienced an increase in the FFDI. The main contributors to this increase are prolonged periods of reduced rainfall and the increased frequency and intensity of extreme heat (Lucas et al., 2007; Clarke et al., 2012). The FFDI has 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., 2012). The increase has been most prominent in southeastern Australia.

Finally, in addition to its influence on fire danger weather, climate change is increasing the length of fire seasons (Clarke et al., 2012). This is an important consideration because it can affect the time available for reducing fire hazard and preparing communities for fire conditions.

In summary, climate change is aggravating bushfire conditions and thus increasing the risk of fire. The introduction of the Catastrophic rating is concrete evidence of this increasing risk.

Heavy rainfall

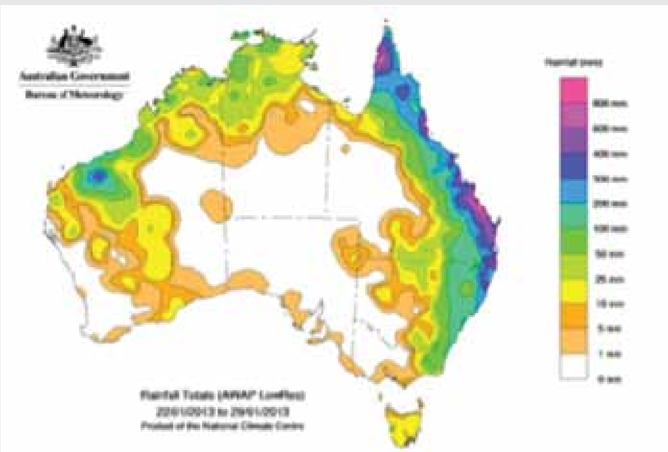
Over the last few years the east coast of Australia has experienced a number of intense rainfall events, triggering large floods that have cost lives, damaged property, inundated ecosystems and caused significant dislocation to local and regional communities.

What happened?

Between 22 and 29 January 2013 extreme rainfall occurred over the east coast of Queensland and the New South Wales coast north of the Illawarra, resulting in severe flooding (BoM, 2013b). Many areas received daily rainfalls greater than 400 mm, with many breaking daily rainfall records (BoM, 2013b) (see Figure 2, Figure 9 and Figure 11). The most impressive record was the one-day rainfall averaged over the Burnett catchment, which was nearly 70% higher than the previous record. The Brisbane river catchment amounts were similar to those observed during the 2011 floods (BoM, 2013b).

This heavy rainfall resulted in severe flooding in many areas along the coast of Queensland and far north New South Wales, although the dry lead-up period led to lesser flooding in some areas compared to the 2011 floods (BoM, 2013b).

Figure 9: Rainfall for the period 22–29 January 2013.



Source: BoM, 2013b

The heavy rainfall was the result of former tropical cyclone ***Oswald*** moving south, just inland of the Queensland coast (BoM, 2013d). ***Oswald*** was formed in the Gulf of Carpentaria on 22 January 2013. When it reached land that night, it weakened to become a slow-moving tropical low pressure system. This system travelled southwards until moving offshore near Sydney on 29 January 2013 (Figure 10; BoM, 2013d).

Figure 10: Path of the low pressure system that was the former tropical cyclone *Oswald*.

Source: BoM, 2013d

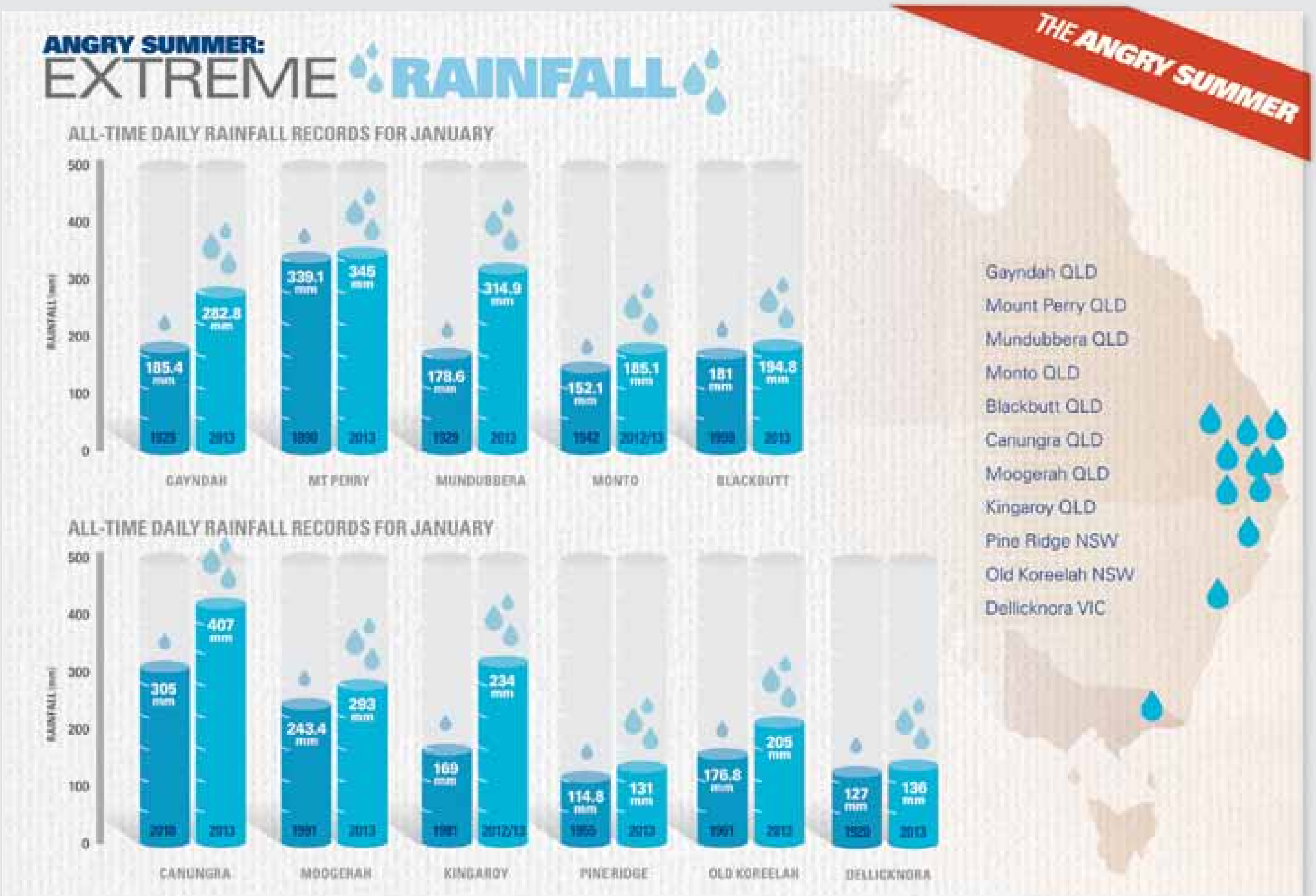
The system brought extreme rainfalls, many of them breaking records (Figure 11):

- On 25 January 2013 many areas around Rockhampton recorded rainfall for a 24-hour period in excess of 400 mm
- On 28 January 2013, the most extreme daily rainfall of the event was recorded over the Gold Coast hinterland/New South Wales border ranges catchment, as well as the edge of the Brisbane River catchment. Sites in both of these catchments recorded rainfall for a 24-hour period in excess of 700 mm
- A large region of the east coast, between Mackay and Newcastle, was close to rainfall records for January
- The 22–29 January rainfall events alone were heavy enough to break the January monthly rainfall records for the area between Rockhampton and Bundaberg

(BoM, 2013b)

In addition to heavy rains, the system brought strong winds and storm surges, high waves and tornadoes.

Figure 11: Record-breaking daily rainfall in Queensland, New South Wales and Victoria during the summer of 2012/2013.



Date source: BoM, 2013b

The extreme rainfall triggered severe flooding in many areas within 200 km of the Queensland and far northern New South Wales coastlines (BoM, 2013b; Figure 12). Areas most affected were the Burnett catchment near Bundaberg in Queensland, and the Clarence catchment near Grafton in New South Wales (BoM, 2013b). Both of these rivers reached record flood peaks (BoM, 2013b). Most other rivers peaked below their highest levels of 2010–11 (BoM, 2013b).

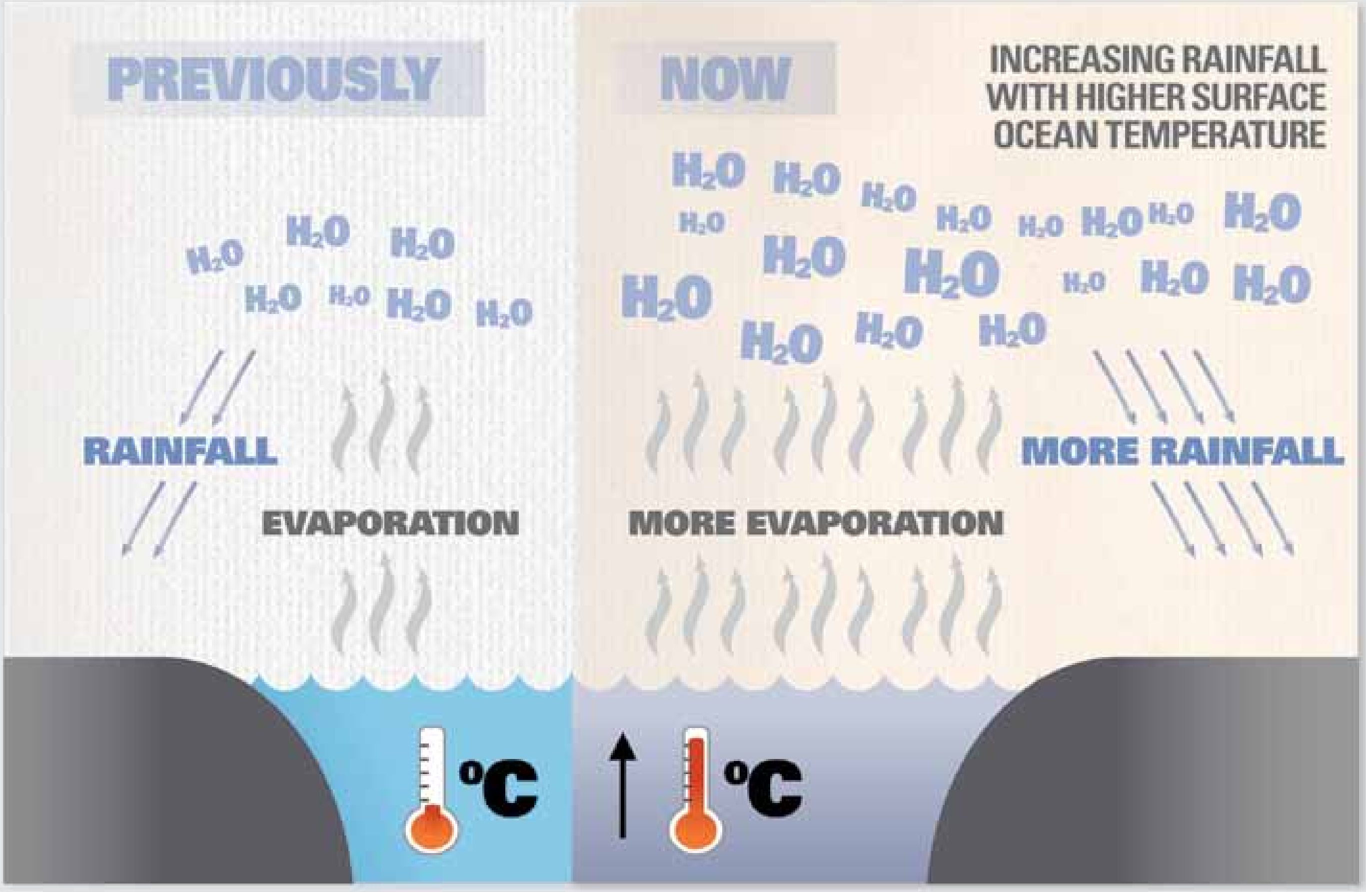
How does climate change influence rainfall?

The basic physics that underpin the connection between a warming climate and more rainfall are well known (Figure 13). Higher surface ocean temperatures drive more evaporation, leading to more water vapour in the atmosphere. This, in turn, leads to more precipitation (rainfall, snow or hail).

Figure 12: Cleaning up flood damage in Avoca, Queensland.

Source: Flikr/ABC Open Bay

Figure 13: The influence of climate change on the water cycle: (LEFT) the pre-climate change water cycle and (RIGHT) the water cycle operating under higher surface ocean and air temperatures. The symbol H_2O represents water vapour.



Observations by scientists worldwide affirm the basic physics demonstrating that heavy rainfall becomes more likely as the climate warms. The world's leading body on climate change, the Intergovernmental Panel on Climate Change (IPCC), assessed observations on a global scale and found an increase in water vapour in the atmosphere from 1988 to 2004, the period over which accurate global measurements are available (IPCC, 2007). The IPCC (2012) further reported that, on balance, it is likely that there has been a net increase in the number of heavy precipitation events around the world, although there is strong regional variation in the trends. A recent analysis of global data since the beginning of the 20th century confirmed the IPCC (2012) conclusion that there are more areas around the world with significant increases in extreme precipitation amounts, intensity and frequency than areas with decreasing trends (Donat et al., 2013).

The extreme rainfall during the 2012/2013 Australian summer, like all the other extreme weather events, occurred in a warmer and moister climate system compared to 50 years ago. Extreme rainfall is consistent with the type of events scientists expect to see more often in a warming climate.

Author

Professor Will Steffen
Climate Commissioner

References:

BoM (Bureau of Meteorology) (2012). *Improving Australia's climate record*. Retrieved from: **http://www.bom.gov.au/water/news/article.php?id=63**

BoM (2013a). *Special Climate Statement 43 – extreme heat in January 2013*. Retrieved from: **http://www.bom.gov.au/climate/current/statements/scs43e.pdf**

BoM (2013b). *Special Climate Statement 44 – extreme rainfall and flooding in coastal Queensland and New South Wales*. Retrieved from: **http://www.bom.gov.au/climate/current/statements/scs44.pdf**

BoM (2013c). *Tropical Cyclone advice number 38*. Retrieved from: **http://www.bom.gov.au/cgi-bin/wrap_fwo.pl?IDW24100.txt**

BoM (2013d). *Tropical Cyclone Oswald*. Retrieved from: **http://www.bom.gov.au/announcements/sevwx/qld/qldtc20130117.shtml**

BoM (2013e). *ACORN-SAT data summary for Canberra*. Retrieved from: **http://www.bom.gov.au/climate/change/acorn/sat/data/acorn.sat.maxT.086071.daily.txt**

BoM (2013f). *Tasmania in January 2013: Record heat, little rain*. Retrieved from: **http://www.bom.gov.au/climate/current/month/tas/summary.shtml**

BoM (2013g). *Fire weather warnings*. Retrieved from: **http://www.bom.gov.au/weather-services/bushfire/**

Clarke, H., Lucas, C. and Smith, P. (2012). Changes in Australian fire weather between 1973 and 2010. *International Journal of Climatology*. DOI: 10.1002/joc.3480

CSIRO and BoM (2007). *Climate change in Australia, technical report*. Retrieved from: **http://www.climatechangeinaustralia.gov.au/technical_report.php**

CSIRO and BoM (2012). *State of the Climate*. Retrieved from: **http://www.csiro.au/Outcomes/Climate/Understanding/State-of-the-Climate-2012.aspx**

CSIRO (2013). Centre for Australian Weather and Climate Research *Fire Weather Index (FWI): Forecasts.* Retrieved from: **http://www.cawcr.gov.au/projects/fwi/2013/0108.php**

Donat, M.G., Alexander, L.V., Yang, H., Durre, I., Vose, R., Dunn, R.J.H., Willett, K.M., Aguilar, E., Brunet, M., Caesar, J., Hewitson, B., Jack, C., Klein Tank, A.M. G., Kruger, A.C., Marengo, J., Peterson, T.C., M. Renom, M., Oria Rojas, C., Rusticucci, M., Salinger, J., Elrayah, A.S., Sekele, S.S., Srivastava, A.K., Trewin, B., Villarroel, C., Vincent, L.A., Zhai, P., Zhang, X. and Kitching, S. (2013). Updated analysis of temperature and precipitation extreme indices since the beginning of the twentieth century: The HadEX2 dataset. *Journal of Geophysical Research*, in press.

IPCC (Intergovernmental Panel on Climate Change) (2007). Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

IPCC (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, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 1–19 pp.

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.

RFS (Rural Fire Service) (2009). *Fire Danger Rating*. Retrieved from: **http://www.rfs.nsw.gov.au/file_system/attachments/Attachment_FireDangerRating.pdf**

RFS (2013a). Worst fire conditions in decades to hit NSW. Retrieved from: **http://www.rfs.nsw.gov.au/dsp_more_info_latest.cfm?CON_ID=19585**

RFS (2013b). More areas reach catastrophic fire danger rating. Retrieved from: **http://www.rfs.nsw.gov.au/dsp_more_info_latest.cfm?CON_ID=19585**

Trenberth, K.E. (2012). Framing the way to relate climate extremes to climate change. *Climatic Change* DOI 10.1007/s10584-012-0441-5

Trewin, B. and Smalley, R. (2013). *Changes in extreme temperatures in Australia, 1910 to 2011*. 19th AMOS National Conference, Melbourne, 11-13 February 2013.

PwC (PricewaterhouseCoopers Australia). (2011). *Protecting human health and safety during severe and extreme heat events*. Retrieved from: **http://www.pwc.com.au/industry/government/publications/extreme-heat-events.htm**

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GPO Box 854 Canberra ACT 2601 Australia
P: +61 2 6159 7624 E: info@climatecommission.gov.au
www.climatecommission.gov.au