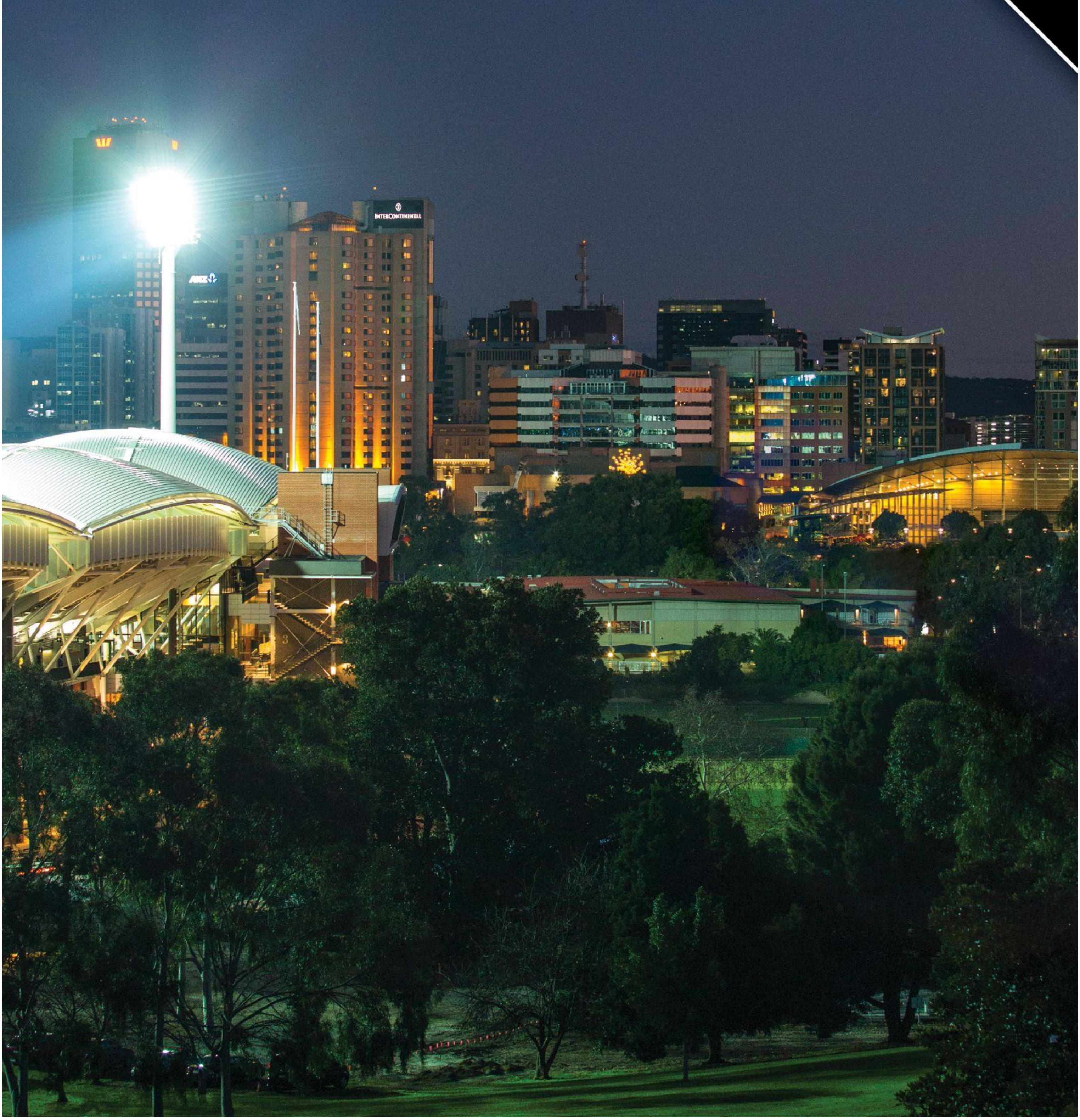
Attachment 10.1

Bureau of Meteorology (BoM): Climate extremes analysis for South Australian Power Network operations

2014

SA Power Networks



Australian Government
Bureau of Meteorology

Climate extremes analysis for South Australian Power Network operations

Heat, lightning, wind and fire weather trends and variability

Published by the Bureau of Meteorology
Author- Darren Ray, Senior Climatologist
Climate Services South Australian Region
Bureau of Meteorology

Table of contents

List of Figures

Executive summary

Introduction

This report analyses trends and variability of climate and weather parameters known to impact South Australia Power Networks (SAPN) operations, and examines possible connections with major modes of climate variability that influence the South Australian climate.

Some analysis is conducted across the South Australian agricultural area which covers all of the SAPN coverage area apart from the northern branches up to Woomera and Hawker. Area averaged data is available for the South Australian agricultural area that provides insight that station data cannot.

Higher temperatures

Analysis across the South Australian agricultural area as a whole, and at individual weather stations, clearly indicate a warming trend in the last few decades of about 1°C in both average daytime and night-time temperatures, consistent with trends observed for Australia.

Average Daily Temperatures (ADT = ½ (Max temp + Min temp)) greater than 32.5°C are known to impact SAPN operations, and the frequency of such events has generally doubled since 2000. Many southern areas which have had few, if any, such days prior to the year 2000, have been experiencing them regularly since then.

With further temperature rises likely over the next 5 to 10 year timeframe, this trend to greater numbers of days with extreme temperatures is likely to continue.

Increased fire risk

Along with increasing temperatures, the number of Severe, Extreme or Catastrophic Fire Danger Rating days in summer has increased by between 1.7 and 2.5 times since 2000, in the Mount Lofty Ranges and at Port Lincoln. This increased fire risk is likely to remain or increase further with increased temperatures over the next 5 to 10 year timeframe.

Thunderstorm and lightning activity

Thunderstorm and lightning activity has varied significantly across South Australia, with low levels of activity prior to the mid-1970's, much increased activity from then until the late 1990's, and somewhat decreased levels since 2000.

Correlations with the Inter-decadal Pacific Oscillation, a major mode of climate variability, suggest increased thunderstorm and lightning activity may occur in the next 10 to 20 year timeframe.

Correlations of thunderstorm activity with Indian Ocean surface temperatures provide some predictability of lightning activity on a 3 to 6 month timeframe.

Vegetation related damage

No increase in either sustained wind events or extreme wind gusts is seen in the available data. It is noted that extreme wind events in the Adelaide region cluster in the period June to December but more particularly August to October.

A significant increase in the duration of heat events, which is likely to cause heat stress in trees, has been observed since the late 1990's. This suggests that when wind events do occur, the increased heat stress may result in more material being blown around by winds.

2 Introduction

This report examines trends and variability of extremes in weather and climate recognised to impact operations and the availability of supply within the operational network maintained by South Australia Power Networks (SAPN).

The report includes a general climate summary for the SAPN network coverage area, and examination of extremes of temperature, fire weather, wind and lightning activity, looking for significant trends, and any variability that can be related to major modes of climate influence relevant to the South Australian region.

A specific focus of the analysis was the potential for SAPN to improve its operational preparedness for weather events through the use of the forecast and outlook information which results from the analysis. This report aims to highlight the weather events which have historically been the most problematic for SAPN.

2.1 The SAPN coverage area.

SAPN's distribution grid supplies the greater metropolitan area, regional population centres and areas in which agricultural activities occur and accompanying towns. This area covers southern South Australia, which generally receives on average 250 mm or more of rainfall annually, much of this in the months from April to October. The SAPN distribution grid also extends north along the Flinders Ranges which also has a 250mm average annual rainfall. The SAPN coverage area also extends outside of the agricultural areas to the north of Port Augusta into the northern pastoral areas of South Australia, covering major regional centres such as Woomera and Hawker.

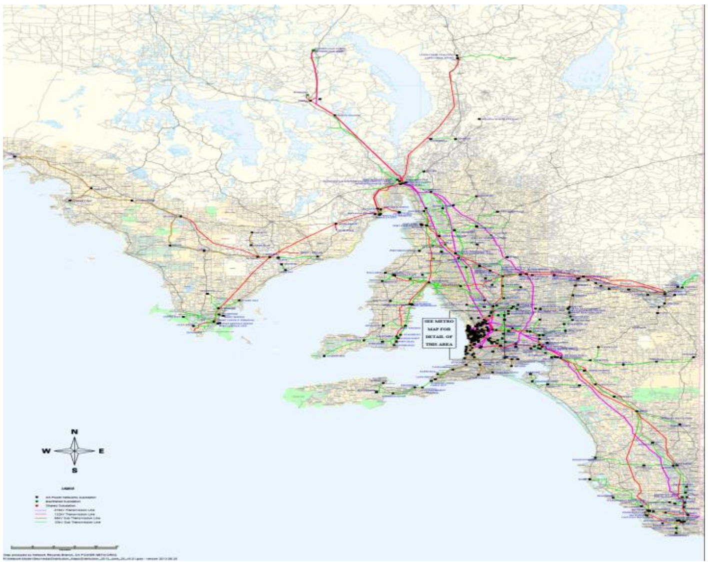


Figure 2.1-1 SAPN network coverage

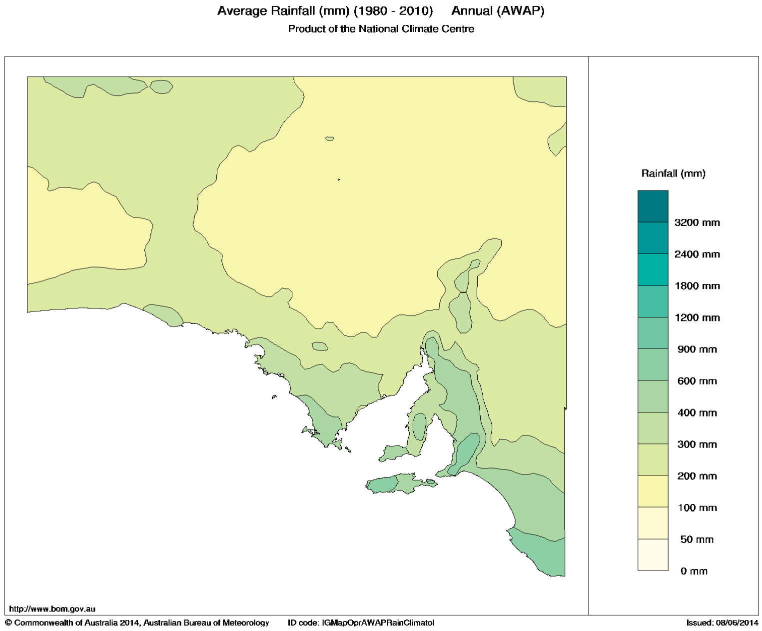


Figure 2.1-2 Annual average rainfall in South Australia (1980 to 2010)

2.2 The climate of South Australia and the SAPN coverage area.

The climate of South Australia, particularly southern areas of the state, is generally described as Mediterranean, meaning the region, being situated in the mid-latitudes, is influenced by the seasonal variations in the position of the belt of high pressure systems that extend around the southern hemisphere south of the tropics.

This variation results in the cooler and wetter conditions experienced as the belt of high pressure moves further north through autumn and winter allowing cold frontal systems to move up over southern South Australia.This results in higher annual rainfall on average across southern South Australia (see Fig 2.1-2), with this falling mainly in the April to October period. Spring sees the belt of high pressure moving southwards with cold frontal systems beginning to retreat south of the continent, and warmer and drier conditions ensuing.

South Australia experiences major differences in spring and summer climate influences to other areas that experience Mediterranean style climates, in that there is the maritime continent to the north of Australia. This area of tropical seas, and the tropical variability in the region, has a strong influence on moisture feeds available for rainfall across the continent through spring and summer, and can contribute to significant rainfall events, and associated thunderstorm and lightning, occurring intermittently through that time of the year.

2.3 Major modes of variability influencing South Australia and the SAPN coverage area.

Major modes of climate variability such as El Niño and La Niña events and Indian Ocean influences impact week to week and season to season the resulting rainfall and thunderstorm activity in spring and summer.

2.3.1 El Niño and La Niña events

El Niño and La Niña events are different phases of patterns of natural variability that occur across the equatorial Pacific Ocean. The normal pattern across the equatorial Pacific Ocean is for trade winds blowing from east to west along the equator to push surface water warmed by the tropical sun towards the western Pacific. Importantly, spring and summer rainfall in Australia is influenced by the location of warmer surface waters. Where waters are warmer, evaporation increases and moist air rises higher into the atmosphere as tropical convection increases.

In El Niño events trade winds weaken allowing warmer water to stay in the central and eastern Pacific Ocean. This sees cooler than usual water around Australia's north, resulting in reduced moisture availability and decreased tropical convection. This reduces rainfall in spring and early summer across Australia generally, and South Australia also.

La Niña events are the opposite phase seeing stronger than usual trade winds enhancing warmer than average surface ocean temperatures in the western Pacific increasing evaporation and tropical convection. This leads to increased spring and summer rainfall generally across Australia, and South Australia also.

Both El Niño and La Niña events are features of natural climate variability that have been occurring for thousands of years, and typically start in late winter or spring returning to neutral conditions in April the following year. The strength of both types of event varies from event to event and there are variations in the number of El Niño events compared to La Niña events on a decade to decade basis, both typically occurring on average every 4 to 7 years. The last moderate to strong El Niño event began in 2006, with the second half of 2010 until April 2011 seeing the occurrence of one of the strongest La Niña events on record, followed by another more moderate event in late 2011 to early 2012. Conditions since April 2012 have been neutral, though there are some indications of weak swings towards El Niño type conditions since mid-2012.

2.3.2 Inter-decadal Pacific Oscillation

This is a feature of climate variability across the Pacific Ocean on ~ 20 to 30 year timescales. The positive phase last seen from the mid-1970's to the late 1990's sees warmer waters in the central and eastern Pacific in a more El Niño like pattern, and the negative phase from the 1950's to the mid-1970's and from the late 1990's onwards, sees the opposite occurring with a more La Niña like pattern (Power et al 2006).

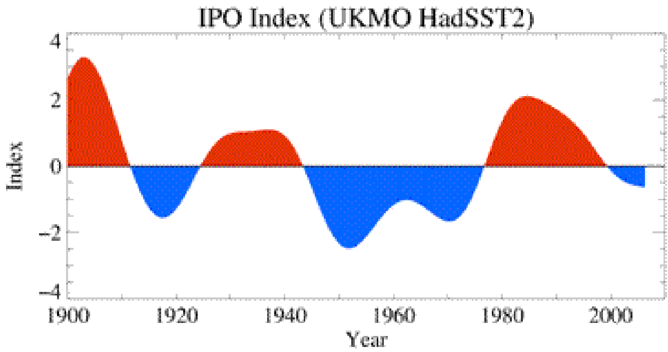


Figure 2.3-1 Inter-decadal Pacific Oscillation (IPO)

2.3.3 Indian Ocean influences

The Indian Ocean to the northwest of Australia also experiences patterns of variability similar in some respects to El Niño and La Niña and with some inter-connections with such events.

A pattern occurs in the tropical Indian Ocean called the Indian Ocean Dipole with this seeing variation in the locations of warmer water along the tropical Indian Ocean through June to October. Positive values of the Indian Dipole index indicate warmer surface water near Africa and cooler water to the northwest of Australia, resulting in reduced evaporation and tropical convection near Australia, hence resulting in decreased rainfall through June to October. Negative values indicate the reverse. Outside of June to October the temperature variability in the oceans to the north-west of Australia in the north-eastern Indian Ocean also can influence weather patterns and rainfall across South Australia.

2.4 Climate trends and change

South Australia's climate is being affected by the significant trends in global and Australian climate changes.

Much research, as detailed in reports on www.climatechangeinaustralia.gov.au and summarised in the Bureau of Meteorology 'State of the Climate' report (State of the Climate 2014) and the Australian Academy of Science Climate Change report (Australian Academy of Science 2010), clearly indicate that significant trends in climate are occurring in Australia and South Australia reflective of similar changes at a global level.

Temperature trends in recent decades within Australia are clear, with an approximately 1˚C increase in temperatures in the last few decades. South Australian temperature trends (Fig 2.4-1 to 2.4-4) are consistent with these global and national trends.

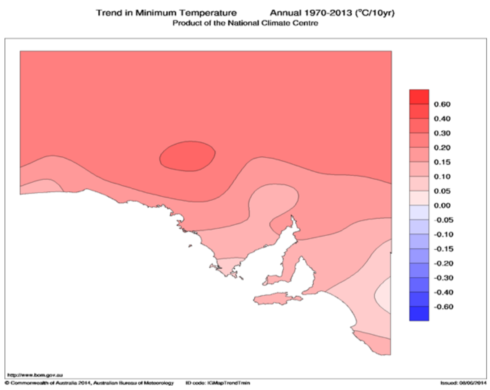


Figure 2.4-1 Trend in annual minimum temperature across South Australia since 1970 (˚C per decade)

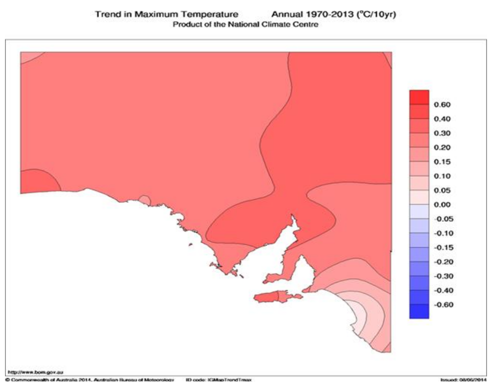


Figure 2.4-2 Trend in annual maximum temperature across South Australia since 1970 (˚C per decade)

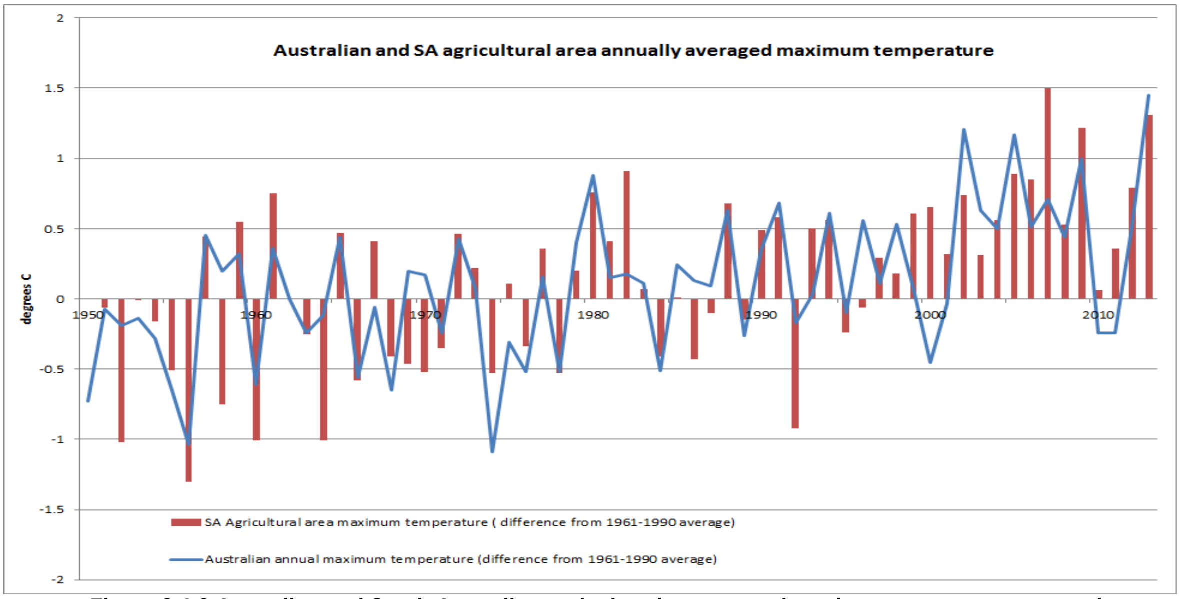


Figure 2.4-3 Australian and South Australian agricultural area annual maximum temperature anomaly (difference from the 1961-1990 average)

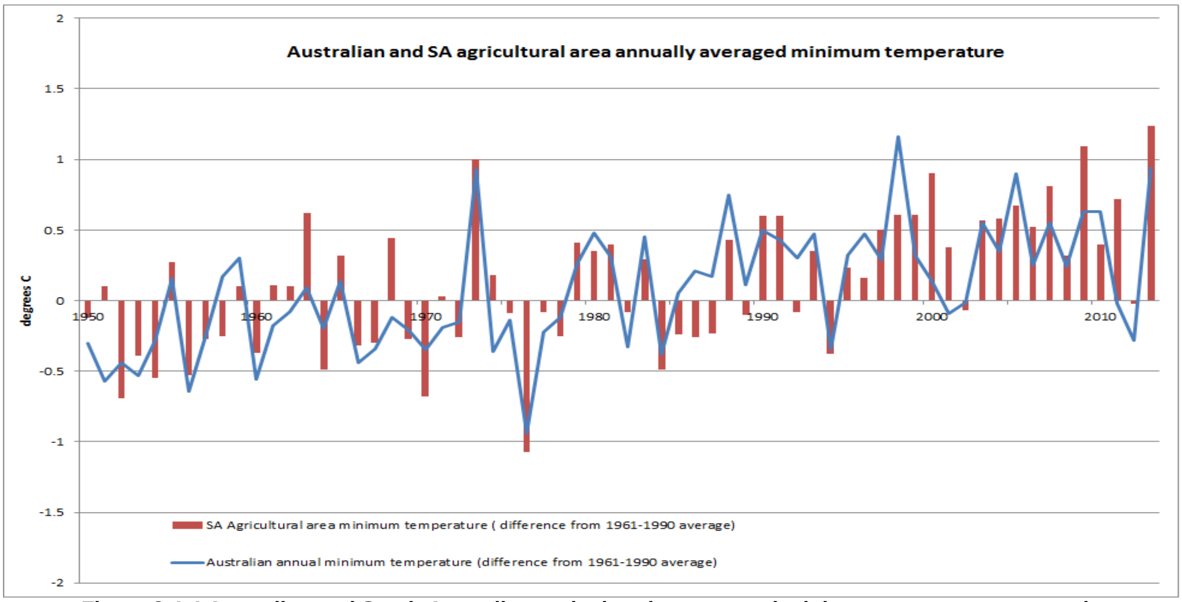


Figure 2.4-4 Australian and South Australian agricultural area annual minimum temperature anomaly (difference from the 1961-1990 average)

While annual and decadal variability is apparent, trends showing an increase in both maximum and minimum temperatures for Australia and for the South Australian agricultural area (covering most of the SAPN coverage area), are clear. Trends in extremes related to these changes in mean conditions will be examined in section 3.

3 Temperature extremes

Section 2 highlights increased average maximum and minimum temperatures around Australia and across much of the SAPN coverage area.

Mean daily temperature, or average daily temperature (ADT) is the average of the maximum and minimum temperature. As might be expected, mean temperature has also increased over recent decades across Australia.

Days where the maximum temperatures exceed 38˚C and the night temperatures stay warmer than 27˚C have been found to increase the risk of transformer failure in SAPN's network. A maximum temperature of 38˚C and minimum of 27˚C results in an ADT of 32.5˚C. Analysis of temperatures across the SA agricultural area, and at individual stations, was conducted using ADT >32.5˚C as a threshold.

All surface air temperature measurements taken by the Bureau of Meteorology since 1910 have been measured in Stevenson screens. This gives a consistent and comparable record since at least that year. Area averaged temperature calculations such as those used for the determination of Australian, and South Australian agricultural area temperatures as part of the Australian Water Availability Project (AWAP) are conducted using an interpolation method from station observations set out in Jones et al 2009.

Temperature analysis was conducted in most instances using the financial year (FY) July to June to cover the summer period for each year, when temperature extremes are most common.

3.1 SA agricultural area heat extremes

3.1.1 Numbers of days ADT>32˚C

The South Australian agricultural districts cover most of the SAPN coverage area. Gridded data derived on a daily basis for this area are produced by interpolation from all available station data by the Bureau of Meteorology, as part of the AWAP project. Figure 3.1-1 below shows for each FY, the FY mean of the Average Daily Temperature, as well as the numbers of days each FY where the ADT exceeded 32.5˚C, a threshold to be referred to as "extreme", and which SAPN has identified will increase the risk of impacts on its power infrastructure.

First it is apparent that there is a significant increasing trend in ADT for each FY since the start of the record. This is clearly consistent with broad-scale temperature increases highlighted in Section 2. Second, this increase in mean temperature is mirrored by an increase in the number of days where the SA Agricultural districts had as a whole, an ADT in excess of 32.5˚C. Such days were very infrequent before the year 2000. In the 40 year period up to 2000, there were 8 years when ADT was above 32.5°C.

Since 2000, 7 out of 14 years have had days when the ADT has exceeded 32.5°C, with approximately twice as many such days in any one extreme FY compared to the earlier 40 years.

With the close match between the increase in extreme days and the increase in mean temperature, and the likelihood of temperatures being sustained at this level or higher for the next 5-10 years, such extreme days as have been observed since 2000 are likely to continue over this period. Longer term, with climate change projections clearly indicating that a further ~1 to 1.5°C increase in temperatures is likely in the next 20 to 30 years (Climate Change in Australia 2007), such extreme days are likely to further increase in frequency and severity.

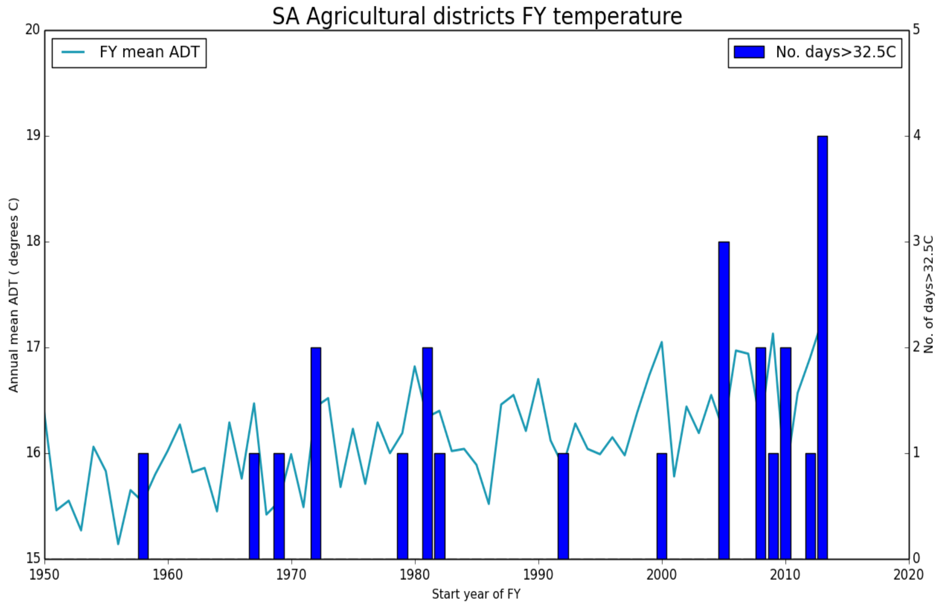


Figure 3.1-1 Mean FY ADT and numbers of days with ADT>32.5°C each FY for the South Australian Agricultural area

3.2 SA station temperature extremes

Temperature records for various stations across the SAPN coverage area were analysed for numbers of days in each FY with ADT>32.5°C. Figures 3.2-1 to 3.2-9 clearly indicate an increasing trend in numbers of days per FY with ADT >32.5°C. This is consistent with the trend in mean temperature plotted in the figures. Some of the stations do show some decadal variability in the numbers of extreme ADT days. The period ~1960 to 1980 sees an increased number of days of extreme ADT, and a decrease from 1980-2000. All stations then display a marked increase in numbers of extreme days from 2000. Stations in the hotter parts of the state, Ceduna, Woomera, Loxton, all experienced days with ADT>32.5°C before 2000 but that number generally increases by 100% or more since 2000. Southern stations that did not experience many or any extreme ADT days have been experiencing them since 2000.

The periods of variability in extreme ADT days generally correspond to periods when mean temperatures are higher as well. This suggests that numbers of extreme ADT days are a result of both the long term increasing trend from climate change, with some decadal variability overlying this.

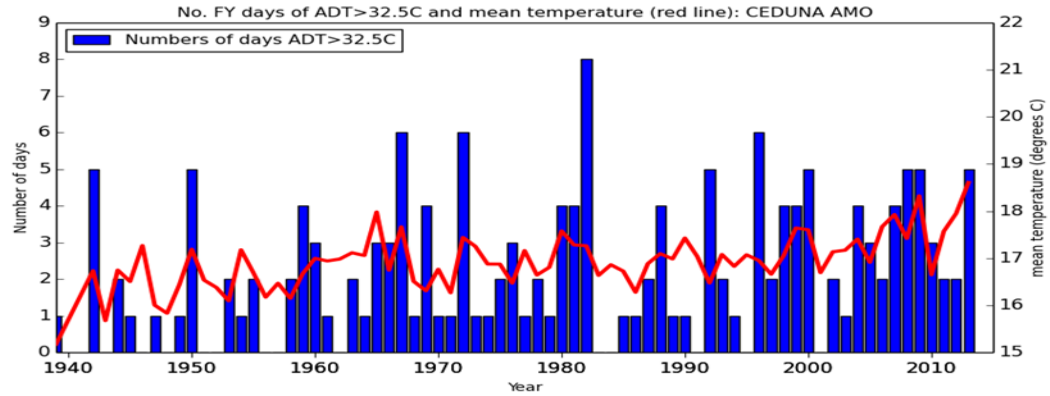


Figure 3.2-1 Mean FY ADT and numbers of days with ADT>32.5°C each FY for Ceduna

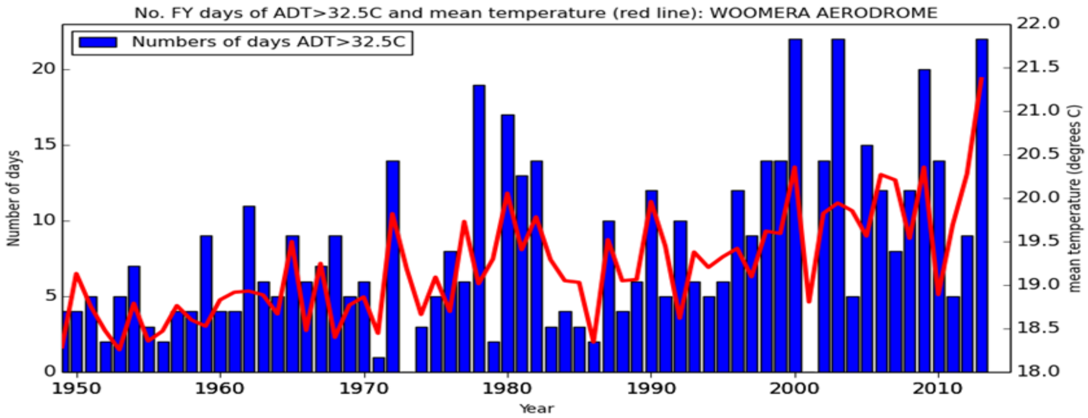


Figure 3.2-2 Mean FY ADT and numbers of days with ADT>32.5°C each FY for Woomera

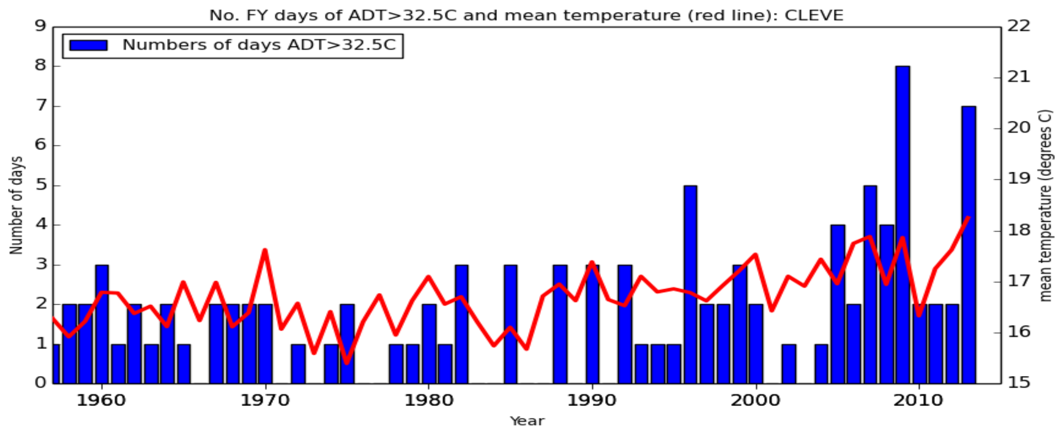


Figure 3.2-3 Mean FY ADT and numbers of days with ADT>32.5°C each FY for Cleve

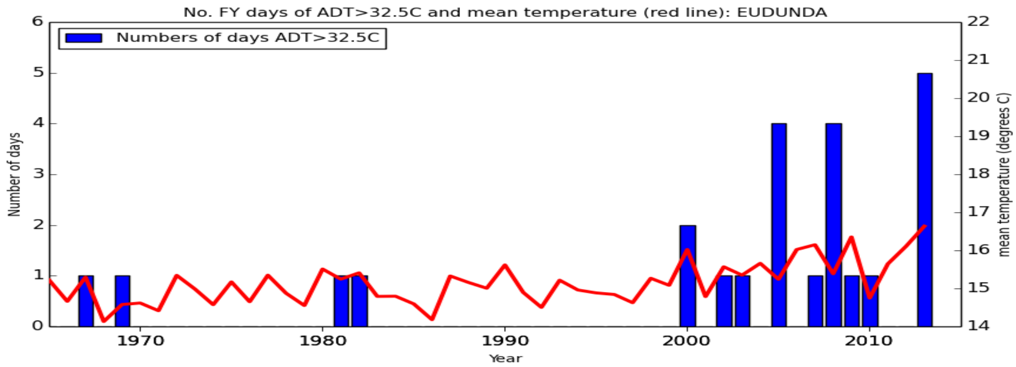


Figure 3.2-4 Mean FY ADT and numbers of days with ADT>32.5˚C each FY for Eudunda

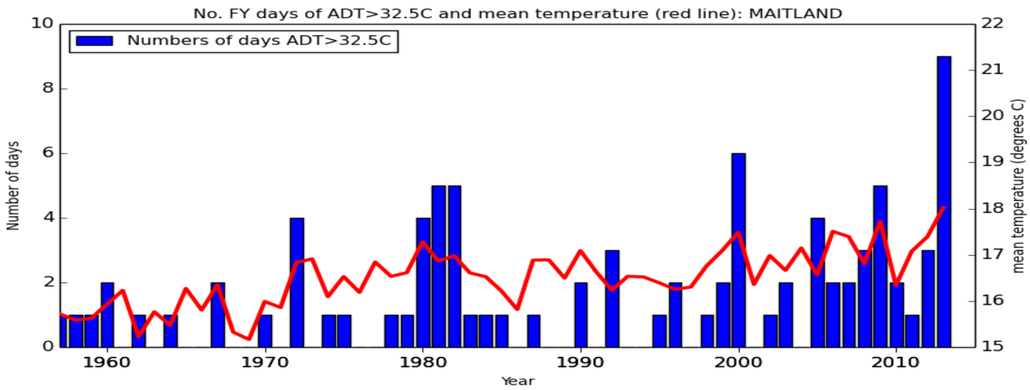


Figure 3.2-5 Mean FY ADT and numbers of days with ADT>32.5˚C each FY for Maitland

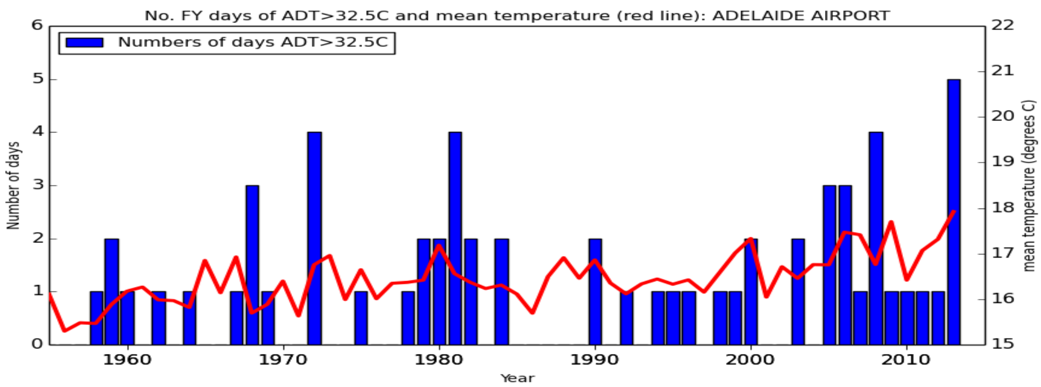


Figure 3.2-6 Mean FY ADT and numbers of days with ADT>32.5˚C each FY for Adelaide Airport

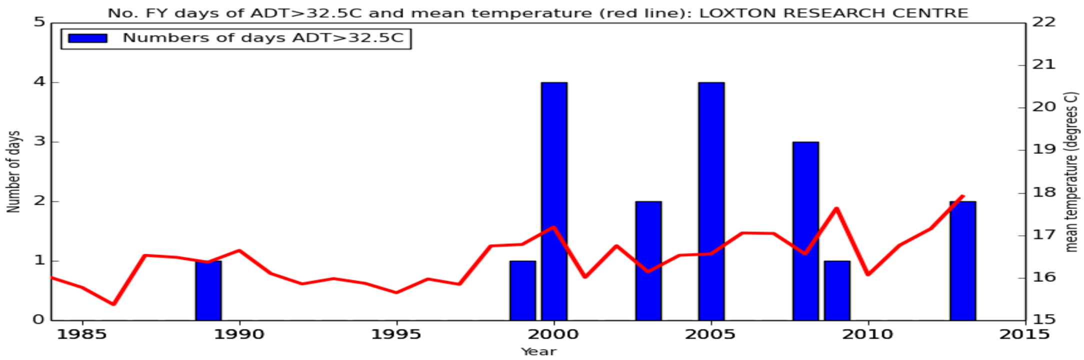


Figure 3.2-7 Mean FY ADT and numbers of days with ADT>32.5°C each FY for Loxton

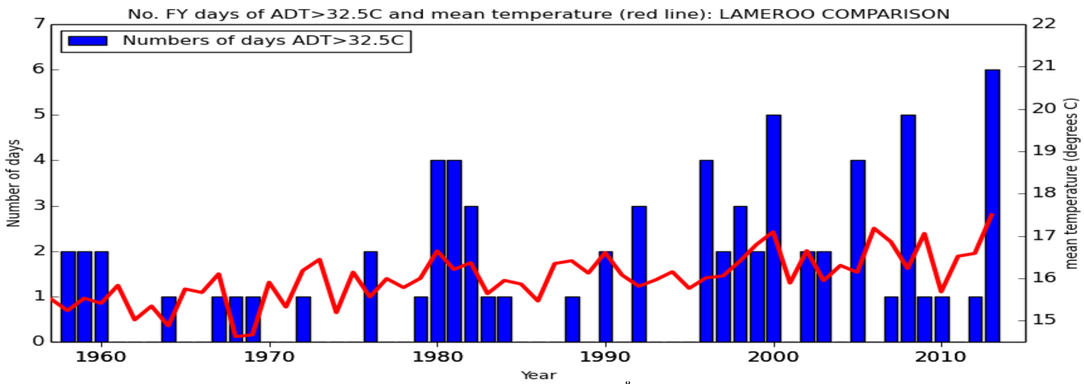


Figure 3.2-8 Mean FY ADT and numbers of days with ADT>32.5°C each FY for Lameroo

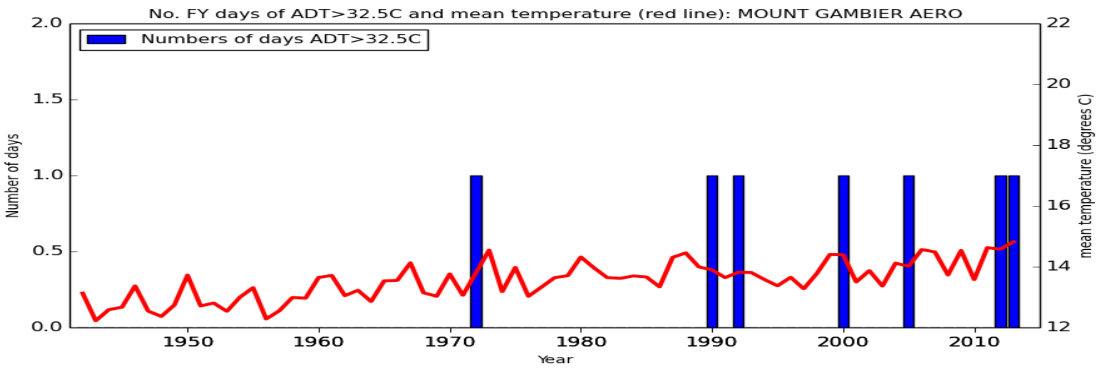


Figure 3.2-9 Mean FY ADT and numbers of days with ADT>32.5°C each FY for Mount Gambier

4 Extremes in fire weather

SAPN's network operations are impacted by extreme fire weather days, particularly in the Mount Lofty Ranges. Analysis was conducted to examine trends and variability in the amount of extreme fire weather in the Mount Lofty Ranges and the Port Lincoln Region.

Fire Danger Index values can be calculated either for grassland conditions, requiring information on fuel loads and curing to obtain Grassland Fire Danger Index values (GFDI), or for forest conditions using the MacArthur Forest Fire Danger Index formula (FFDI), requiring wind speed, air temperature, relative humidity and Drought Factor.

Wind speed, relative humidity and air temperature data is available from Bureau of Meteorology stations on a half-hourly or hourly basis for many sites going back to the early 1990's from aviation format observations (METARS). Past fuel load and curing data is incomplete and hence calculating past values of GFDI values with accuracy prior to the year 2000 would be inaccurate.

For this analysis, summer FFDI values were calculated from half hourly data from METARS reported from Bureau of Meteorology stations, according to MacArthur FFDI formula:

FFDI= e to the power (n(2)-0.45+(0.987ln(DF))-(0.0345RH)+(0.0338T)+(0.0234V))

Where: DF = Drought Factor (dimensionless number between 0 and 10)
T = air temperature (°C)
V = 10 minute mean wind speed at a 10 metre level (km/h)
RH = relative humidity (%)

To simplify the calculation DF was assumed to be 10, which is a reasonable assumption for summer conditions, but may result in some overestimation of FFDI. However, as this is applied consistently across the record, it should not influence trends significantly.

It is recognised that the METAR format utilised by the Bureau of Meteorology has the limitation of not always recording a 10 minute average wind speed in certain conditions. This may result in over estimation of FFDI in some conditions, though once again is consistent across the record so would not significantly impact trends.

Forest Fire Danger Index values in excess of 50 have been examined as a threshold impacting SAPN's operations, these values being Severe, Extreme or Catastrophic according to CFS Fire Danger Ratings.

4.1 Frequency of extreme fire weather

Figures 4.1-1 to 4.1-4 show summer time FFDI for all available METAR observations for stations with longer lengths of record in the Adelaide region, including the Adelaide Hills and Barossa Valley, as well as from the site at Port Lincoln aerodrome.

There is no clear correlation with major climate influences observed in the variation year to year of the number of Severe or higher FFDI values, but all sites show a significant increase in numbers of hours of FFDI >50 each summer from 2000 onwards, with very high numbers for weather stations in the Adelaide region in the last 2 years. This general increase in Severe or higher FFDI is consistent with background warming trends noted in Sections 2 and 3, with numbers of hours of FFDI>50 from year 2000 onwards being 1.7 to 2.5 times the values prior to 2000 (Table 4.1-1) and in the last 2 years the numbers of hours are 2 to 3 times higher again.

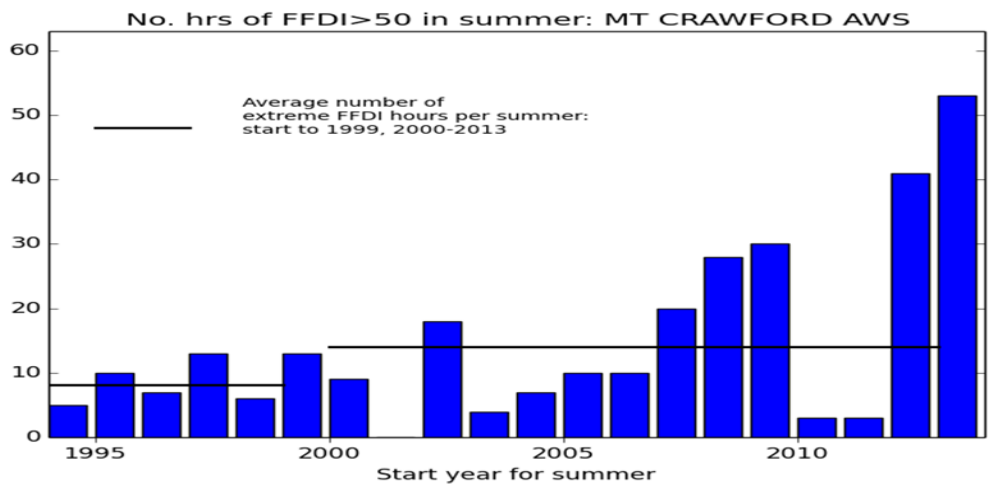


Figure 4.1-1 Number of hours per summer with FFDI >50 for Mount Crawford in the Adelaide Hills

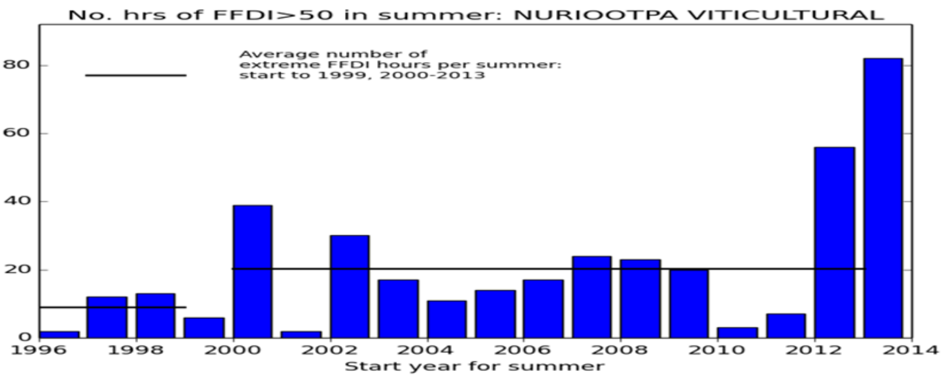


Figure 4.1-2 Number of hours per summer with FFDI >50 for Nuriootpa in the Barossa Valley

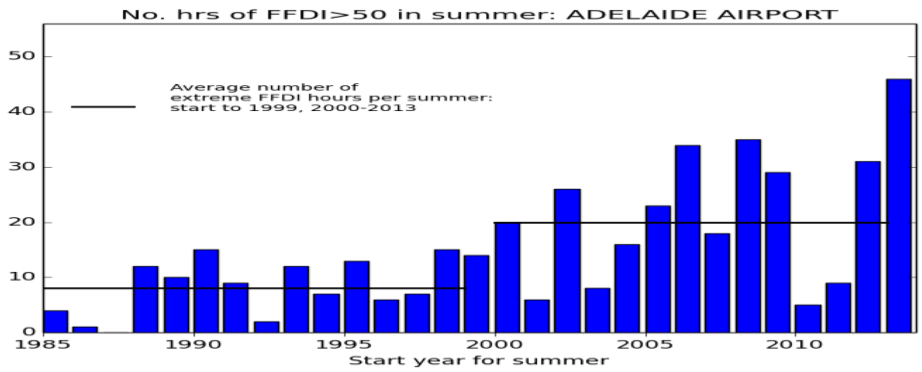


Figure 4.1-3 Number of hours per summer with FFDI >50 for Adelaide Airport

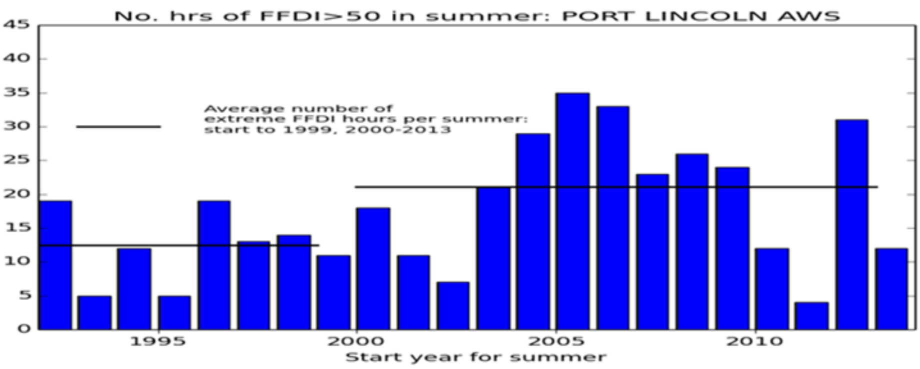


Figure 4.1-4 Number of hours per summer with FFDI >50 for Port Lincoln Airport

Station	pre 2000 hours of FFDI>50 per DJF	post 2000 hours FFDI>50 per DJF	x change
ADELAIDE AIRPORT	8.1	20.0	2.5
MT CRAWFORD AWS	8.2	14.1	1.7
NURIOOTPA VITICULTURAL	9.0	20.2	2.2
PORT LINCOLN AWS	12.4	21.1	1.7

Table 4.1-1 Average numbers of hours per summer of FFDI>50 pre and post 2000

In looking for significant trends in the figures above, the relatively short length of the record must be taken into account. However the increasing trend in FFDI values is clear, and extends through the longer record available at Adelaide Airport. These trends are also consistent with other work looking at trends in Australian fire weather such as Clarke, Lucas and Smith (2012), who found significant positive trends in accumulated FFDI and FFDI extremes across southern Australia.

As there has not been a significant change in wind events in recent decades (further discussed in Section 6) recent increases in FFDI are likely to be strongly driven by the significant temperature increases seen in Sections 2 and 3. With temperatures expected to continue to at least maintain recent levels or increase over the next 5 to 10 years it is expected that the increased levels of fire weather risk observed since 2000 will continue.

5 Lightning and thunderstorm activity across SAPN regions

With power lines often the most elevated object in rural areas of South Australia, power line outages due to lightning strikes are of interest to SAPN network operations.

Records of lightning and thunderstorm activity are subject to some limitations. The technology for detecting lightning strikes is a relatively recent development, with its deployment in Australia on a widespread basis commencing in late 1999, and in some regions numbers of detectors was insufficient to provide accurate coverage until the mid- 2000's. Prior to 1999 the only reliable indication of lightning and thunderstorm activity is from manual observations.

For this analysis, manual thunderstorm observations from South Australian Bureau of Meteorology Meteorological Offices in Woomera, Ceduna, Adelaide Airport and Mount Gambier were used. Also, as Mildura is just across the South Australian border its observations were also used to give an indication of thunderstorm activity in the Riverland region.

Manual observations are available since the early to mid-1950's at synoptic hour periods (every 3 hours). The completeness of the 3 hourly observations across a day has varied through time. Since 2010 Woomera, Ceduna, Mount Gambier and Mildura have moved to an observation program that has less complete observations on weekends. Taking these factors into account, it was decided that the manual observations from 0600 hours to 1500 hours synoptic observations, which are available consistently from 1955 at all of the above stations until 2010, would be used.

All available lightning detection data has been utilised, covering the FY periods beginning in July 2000 to the FY ending June 2013. Because of the sparse lightning detection network coverage within South Australia prior to ~2004, lightning detection data prior to that period must be viewed with caution. However this data has been utilised to allow maximum overlap with available manual observations.

5.1 Lightning detection across SAPN regions

In consultation with SAPN, several regions were set to examine numbers of strikes per FY, as per the map below:

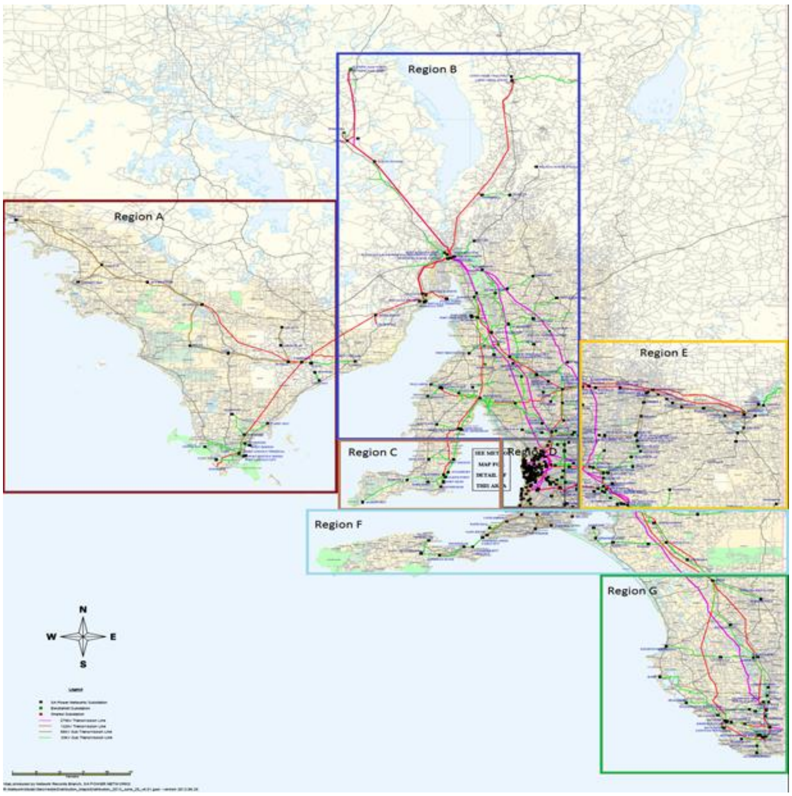


Figure 5.1-1 Regions used for lightning strike analysis across SAPN coverage area

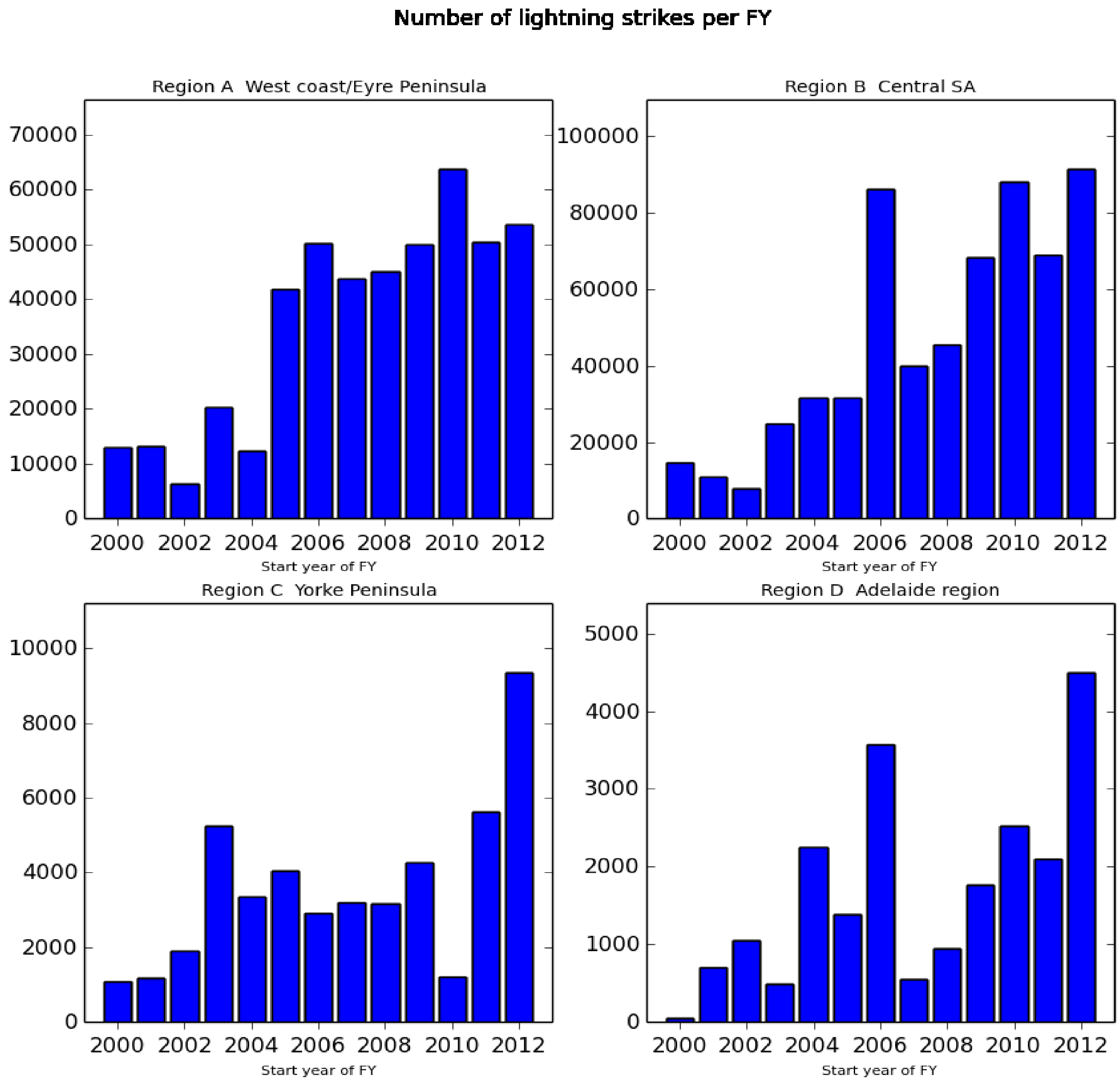


Figure 5.1-2 Numbers of lightning strikes per FY across each regions A to D

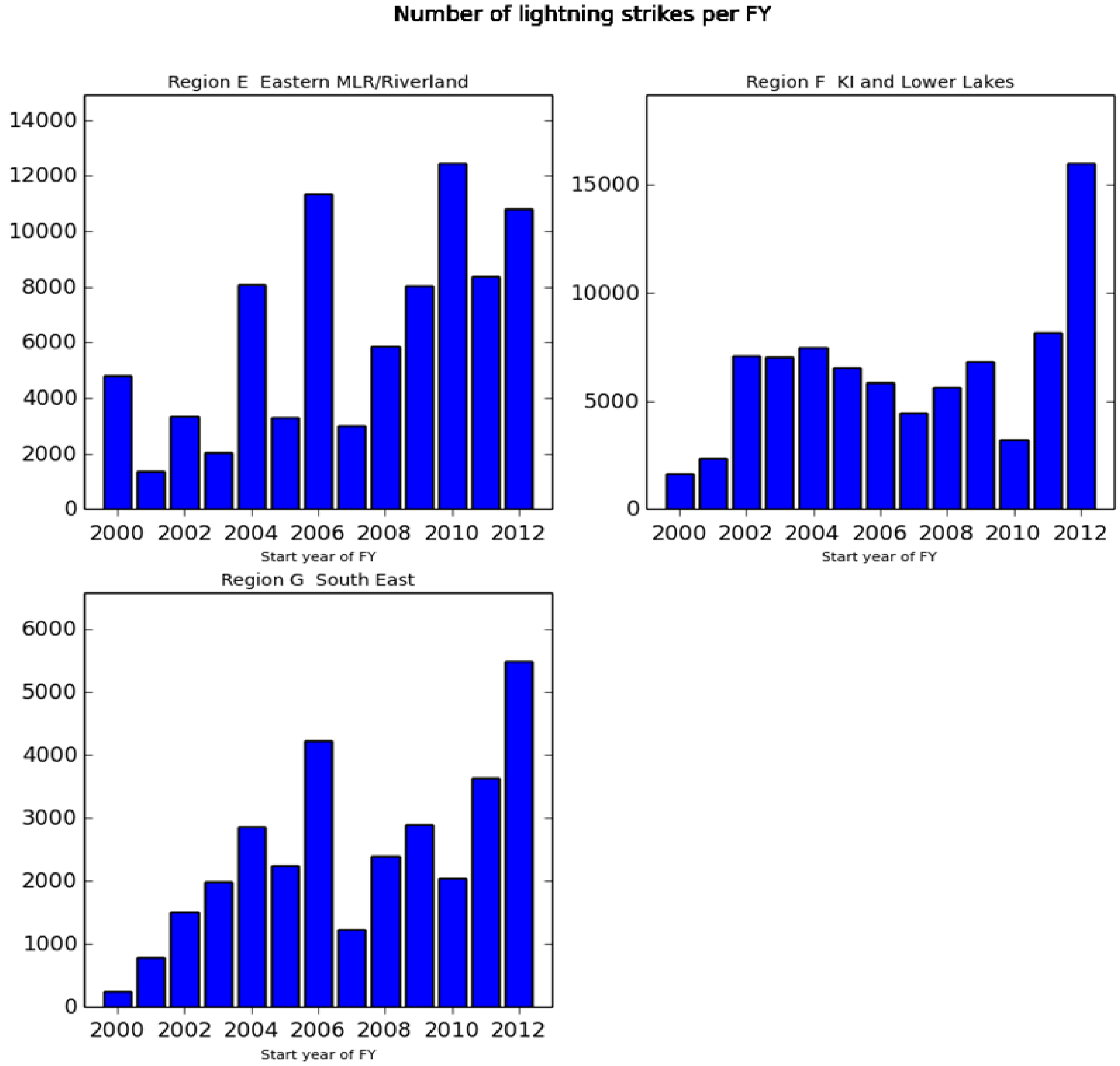


Figure 5.1-3 Numbers of lightning strikes per FY across each regions E to G

5.2 Station thunderstorm and lightning reports

To explore trends in thunderstorm and lightning activity across South Australia all thunderstorm reports (observations conducted by Bureau of Meteorology observing staff plus present and past weather codes >90) were summed for synoptic observations for 0600 to 1500 hours local time. This time period was used as this gave the most consistent set of observations across the available manual observation record.

The number of lightning detection system strikes was summed for each FY for all ground strikes within a radius of 25km of the weather station. This is the radius within which thunderstorm activity would be heard, and lightning activity observed. This was done to provide an indication of thunderstorm activity prior to the start of the lightning detection system record, and allow comparison between the lightning detection observations and the longer manual thunderstorm observations.

Figures 5.2-1 to 5.2-5 below show sums of manual observations and close lightning strikes for weather stations across South Australia providing observations relevant to the SAPN coverage area. Mildura was also included as explained earlier.

The correlation between lightning strike numbers and manual thunderstorm reports in general is good, suggesting that the manual thunderstorm observation provides a useful indication of thunderstorm and lightning activity as far back as 1955.

There is significant decadal variability in thunderstorm activity, with relatively lower levels from the 1950’s, a significant increase during the 1970’s which persists until ~2000, and a significant decrease in thunderstorm activity after 2000, though higher than the 1950’s to 1970’s. Numbers of lightning detection system reports do show higher numbers of strikes in the last few years both in close vicinity to stations, and across regions, as seen in Figures 4.1.1 and 4.1.2. Comparing these to the numbers of thunderstorm reports for the period suggests that there may have been levels of thunderstorm activity and hence likely increased lightning activity at least comparable to, if not exceeding, numbers in recent years in the period from the 1970’s into the 1990’s. The exception to this is seen at Mildura where levels in recent years are as high as any earlier period indicating that perhaps lightning activity in the Riverland area may be as high as at any previous time.

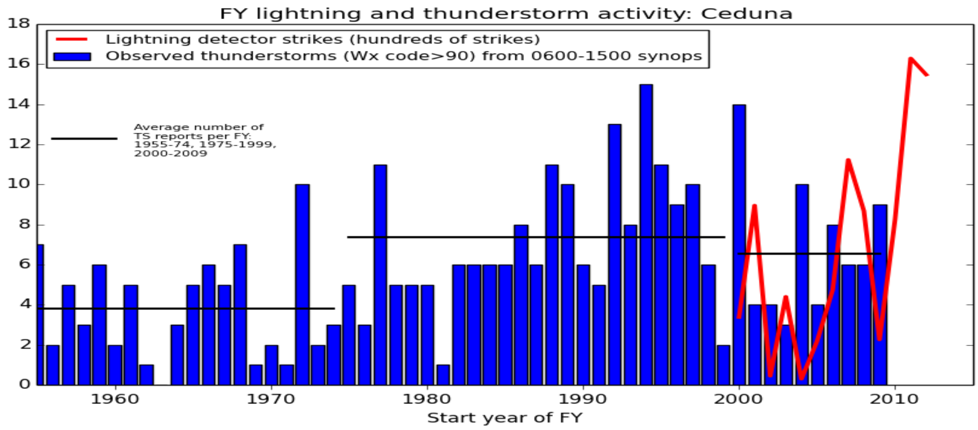


Figure 5.2-1 FY numbers of lightning strikes and thunderstorm reports near Ceduna

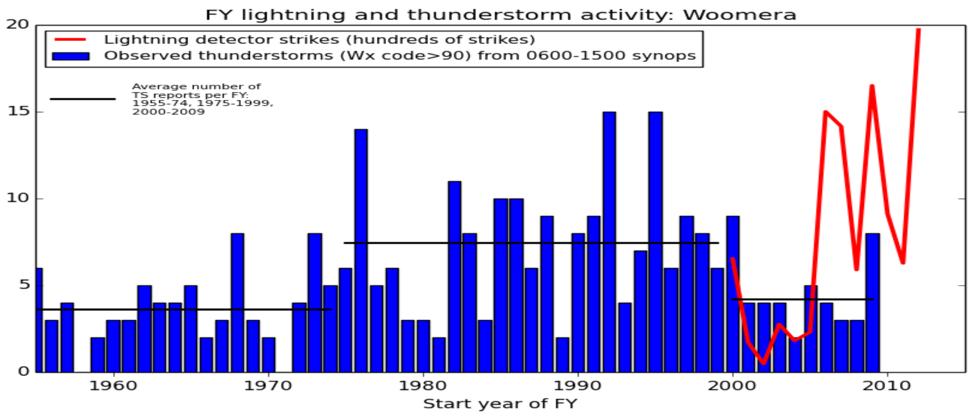


Figure 5.2-2 FY numbers of lightning strikes and thunderstorm reports near Woomera

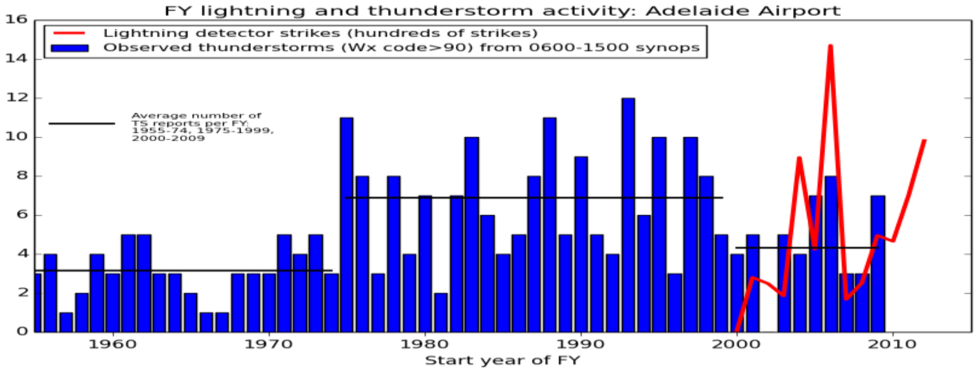


Figure 5.2-3 FY numbers of lightning strikes and thunderstorm reports near Adelaide Airport

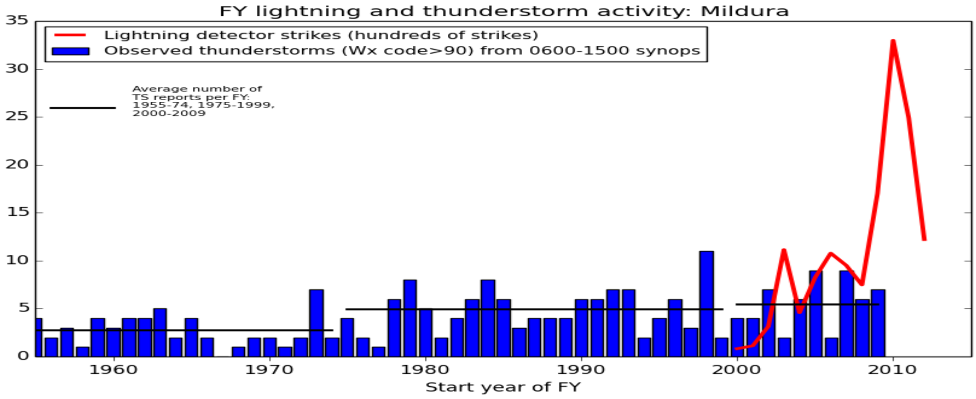


Figure 5.2-4 FY numbers of lightning strikes and thunderstorm reports near Mildura

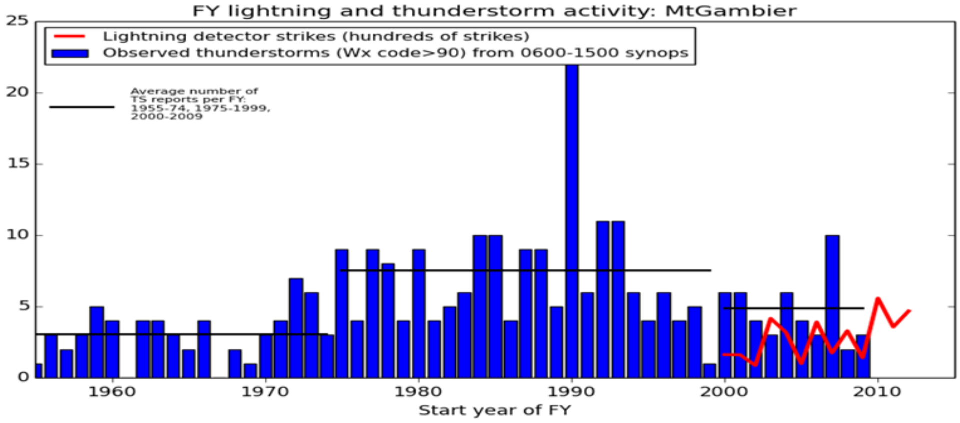


Figure 5.2-5 FY numbers of lightning strikes and thunderstorm reports near Mount Gambier

5.3 Influences of major modes of climate variability on thunderstorm and lightning activity

Section 5.2 above discusses significant decadal variability in thunderstorm reports across stations in the analysis. It is not immediately clear what is underlying the decadal variability observed across these stations. Every effort has been made to ensure this variation in numbers of observed thunderstorm activity is not due to any changes in Bureau of Meteorology observing practice and variations in the observational program. Decadal variability over the same periods observed in other meteorological parameters such as surface temperature as seen in Fig 3.1-1 and 2.4-3 and 2.4-4 suggests this is a real phenomenon, with some underlying meteorological or broad-scale climatic influence.

It is of interest to note that the periods of lower thunderstorm activity (1950's to mid-1970's and ~2000's onwards) correspond to periods of negative Inter-decadal Pacific Oscillation (IPO) values, with increased numbers of thunderstorm reports occurring during a period of positive IPO values from the mid-1970's to 2000. The IPO is a broad-scale feature of variability in the Pacific Ocean that influences ocean temperature patterns across the Pacific Ocean and around northern Australia on a roughly 30 year cycle. Research on the IPO has established connections with variability in El Niño / La Niña events and correlations with temperatures across Australia (Power et al 2005). While the mechanism and variability of the IPO is still an area of ongoing research, if phases of the IPO are the underlying cause of the observed thunderstorm variability, it suggests a significant increase in thunderstorm and lightning activity may be anticipated in ~10 to 20 years with a shift back into the positive IPO phase.

Section 5.1 shows a significant increase observed in lightning strike reports from ~2004 across all regions, particularly for the western and central regions, A and B. This is likely due to increased sensor deployment at that time increasing numbers of recorded lightning strikes. The years with highest numbers of strikes across most regions are 2012/13 and 2006/07, with the latter an El Niño year and the former a year of weak El Niño like features. While this might suggest some correspondence between El Niño events and lightning activity, 2002, another El Niño year saw lower strike rates, and 2010/11, a very strong La Niña event is one of the higher years in the short record.

Correlations with climate influences on a year to year basis such as El Niño /La Niña variability and variability in the Indian Ocean to the northwest of Australia were examined with respect to the longer thunderstorm observation record.

No significant correlation was found between El Niño / La Niña variability as indicated by ocean temperature anomalies in what is known as the Niño 3.4 region in the central Pacific. Positive temperature anomalies in this area greater than 0.8°Cindicate El Niño conditions, and negative anomalies greater than 0.8°Cindicate La Niña conditions.

Neither numbers of thunderstorm reports across stations, or numbers of detected lightning strikes across spring and summer show any strong correlation with Niño 3.4 temperature anomalies. This is somewhat disappointing as El Niño and La Niña variability is the most predictable of climate influences, and a significant correlation with El Niño/ La Niña variability would provide some ability to forecast levels of lightning activity up to 9 months ahead.

To examine possible Indian Ocean influences, north-eastern (NE) Indian Ocean temperature anomalies to the northwest of Australia were correlated with both lightning and thunderstorm activity across the seasons July to October (JASO), and November to March (NDJFM). No strong correlation was found between station thunderstorm reports and NE Indian Ocean temperatures in JASO, though a slight –ve correlation with some significance can be seen at Woomera. Correlations with Indian Ocean Dipole events are slightly stronger and more significant for all stations apart from Mount Gambier (see Fig 5.3-1 below).

For the NDJFM period, all stations show positive correlation with NE Indian Ocean temperature anomalies to the NW of Australia with numbers of thunderstorm reports, though the correlations are either weak or not significant except at Mildura and Adelaide Airport (Fig 5.3-2 below).

The ability to forecast the phase of the Indian Ocean Dipole and ocean temperature anomalies in the Indian Ocean several months in advance with ocean forecasting systems such as the Bureau of Meteorology's POAMA model, and the correlations above may supply some predictive capacity of levels of lightning activity across SAPN network regions.

Forecasts of a positive phase of the Indian Ocean Dipole suggest a higher risk of increased lightning activity across central and northern areas for July to October, while warmer oceans in the NE Indian Ocean also suggest an increased risk of lightning activity for the November to March period across the central districts of South Australia.

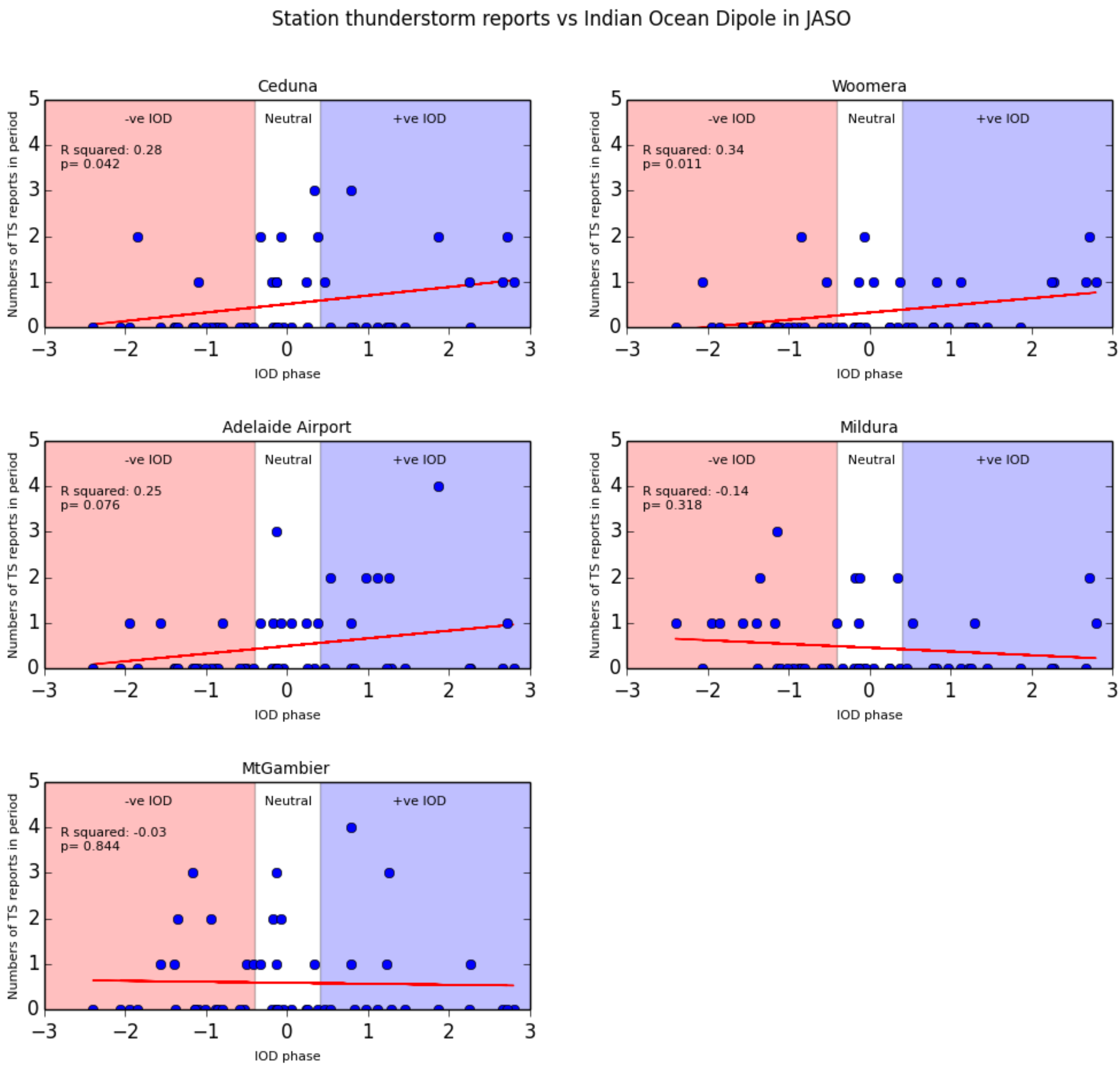


Figure 5.3-1 Numbers of thunderstorm reports for SA and Mildura stations compared with IOD phase for July to October

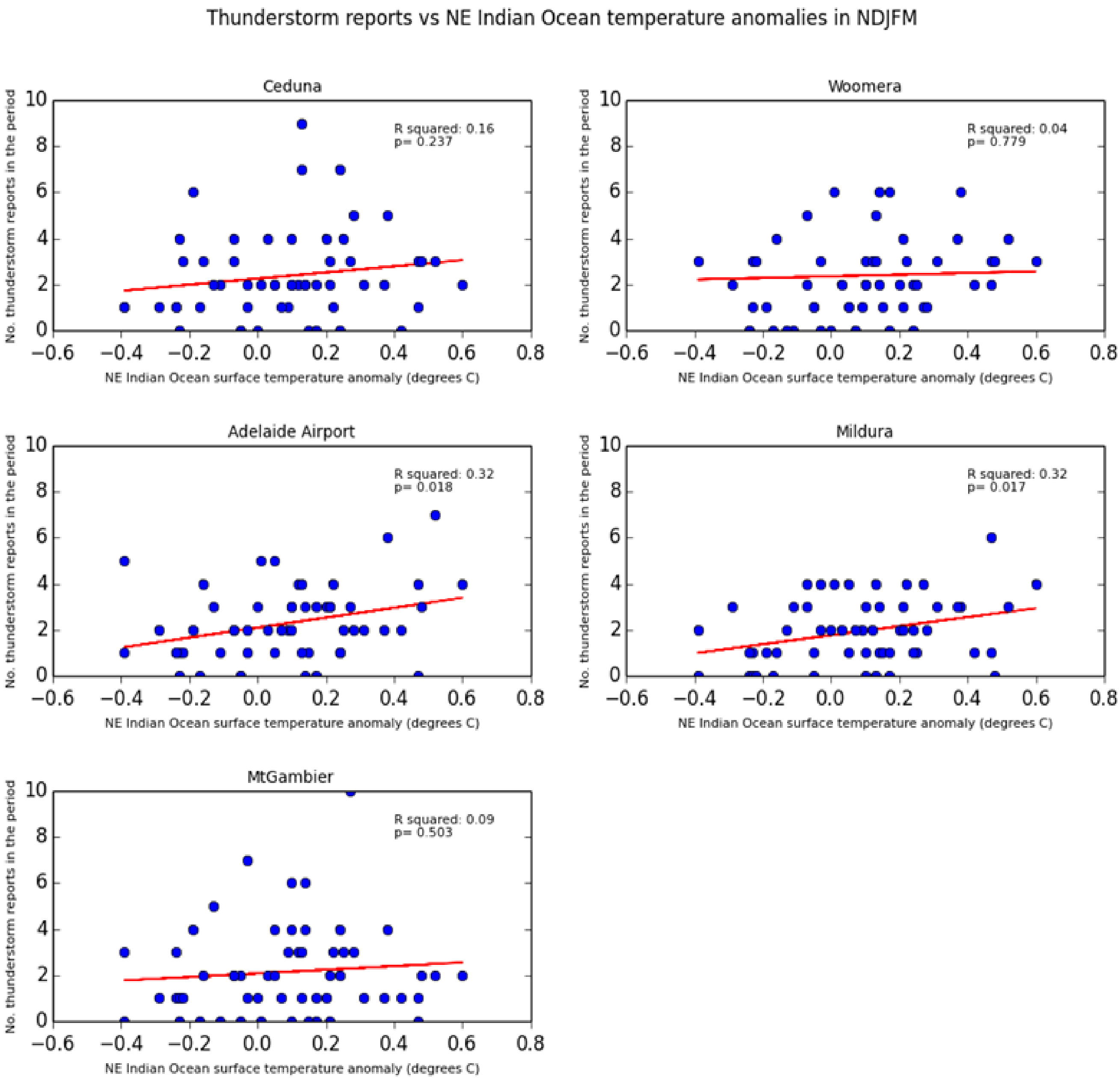


Figure 5.3-2 For November to March, numbers of thunderstorm reports for SA and Mildura stations compared with temperature anomalies in the NE Indian Ocean

6 Wind events impacting SAPN operations

SAPN networks can be impacted by wind events, either sustained periods of strong winds or severe wind gusts, blowing material from trees onto power lines causing shorting and loss of power. This is particularly relevant for the Adelaide metropolitan area and Mount Lofty Ranges.

This section examines available wind data in the Adelaide and Mount Lofty Ranges area for trends and variability that might impact the frequency of events that would impact the SAPN network. It's important to note that the available wind data records are relatively short in comparison to other weather parameters such as rainfall and temperature.

Research related to climate change has examined the impact of a changing climate on tree health. Events in which material from trees is blown onto power lines may be made worse by heat stress in trees under warming conditions. With this in mind, trends in heat extremes are also examined.

6.1 Wind extremes

Wind run is the accumulation of wind speeds through a 24 hour period at a location. Wind run records are typically available from Bureau of Meteorology automatic weather stations from the 1990's. Adelaide Airport has a longer record using earlier wind run measurement apparatus, and while not ideally placed to represent Adelaide Hills wind patterns, has a significantly longer record than other stations.

Maximum wind gusts are reported as the maximum 1 second wind speed recorded in any 10 minute period at a location.

The analysis in figures 6.1-1 to 6.1-4 show the highest daily wind run and the maximum wind gust recorded across each FY, with the month in which it occurred plotted over the top. The records for the Mount Lofty Ranges stations are not long enough to highlight any trend. The Adelaide Airport site has a significant step change in variability from the late 1980's but examination of station records indicate this is likely due to a change in the type of recording instrument at that time rather than any change in wind extremes.

The lack of significant trends in wind speeds is consistent with analysis done for the periods 1948-2006 by Troccoli et al 2012.

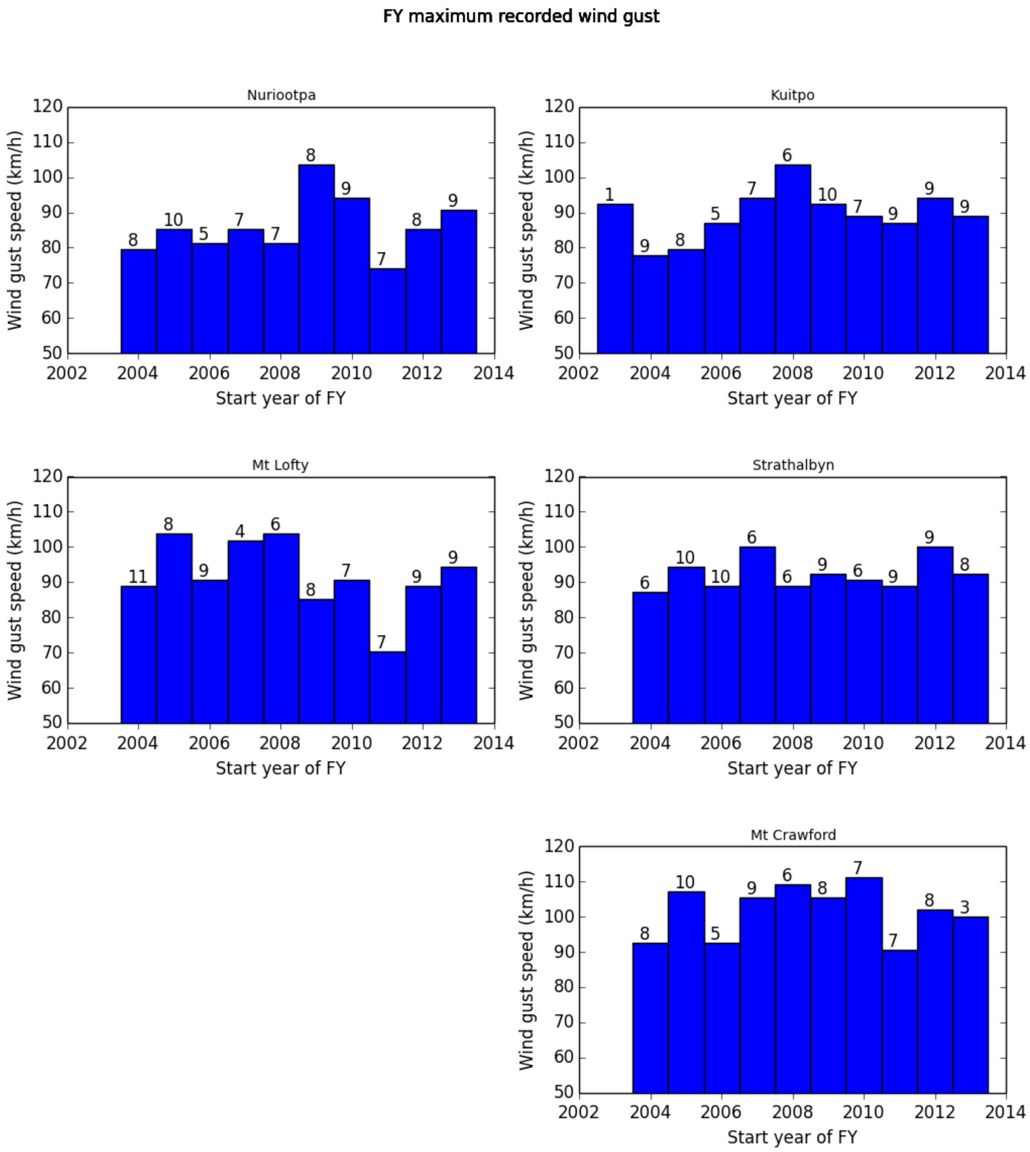


Figure 6.1-1 Maximum recorded wind gust per FY for Adelaide Hills stations (month of occurrence is shown over the bar plot)

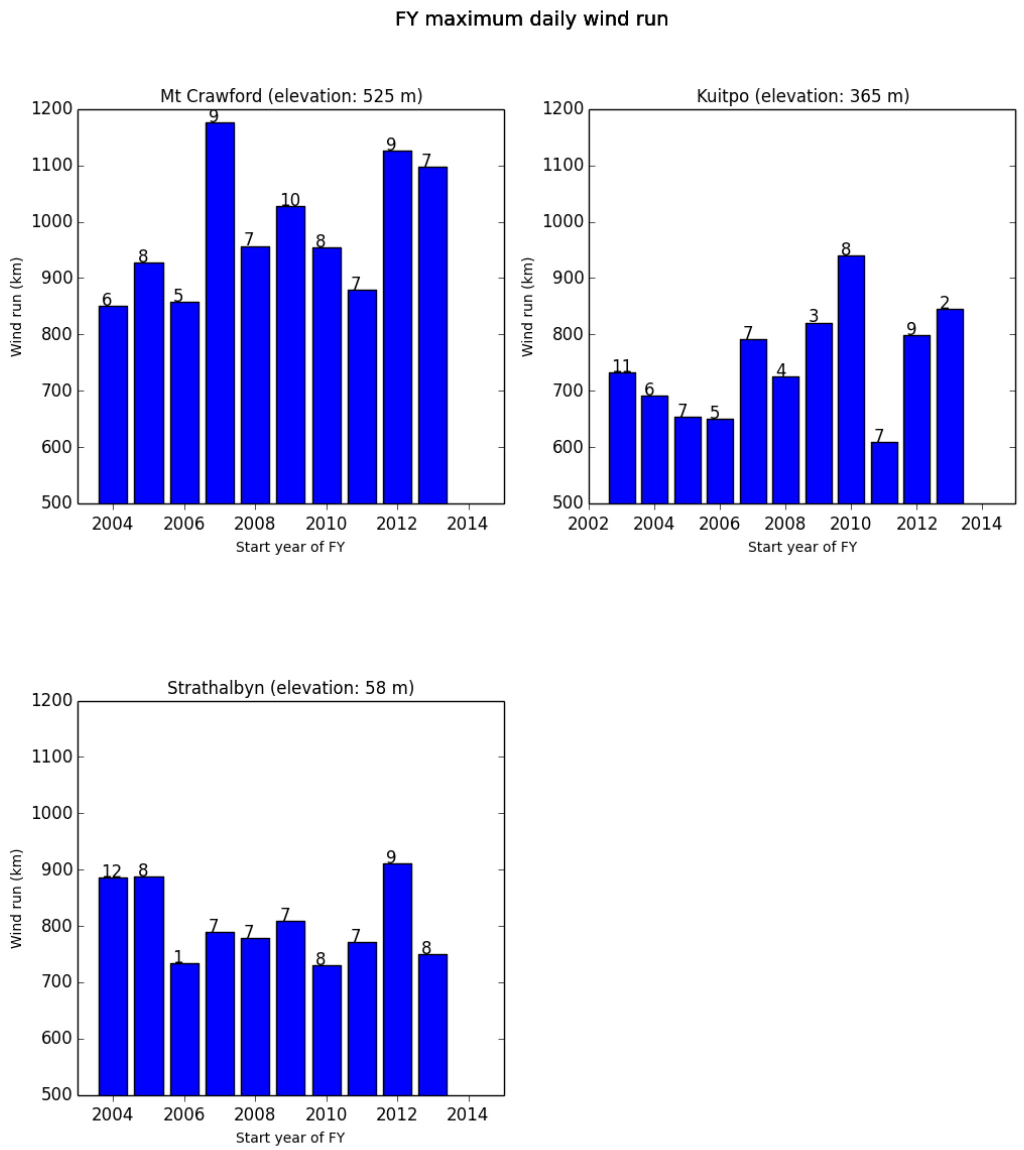


Figure 6.1-2 Maximum daily wind run per FY for Adelaide Hills stations

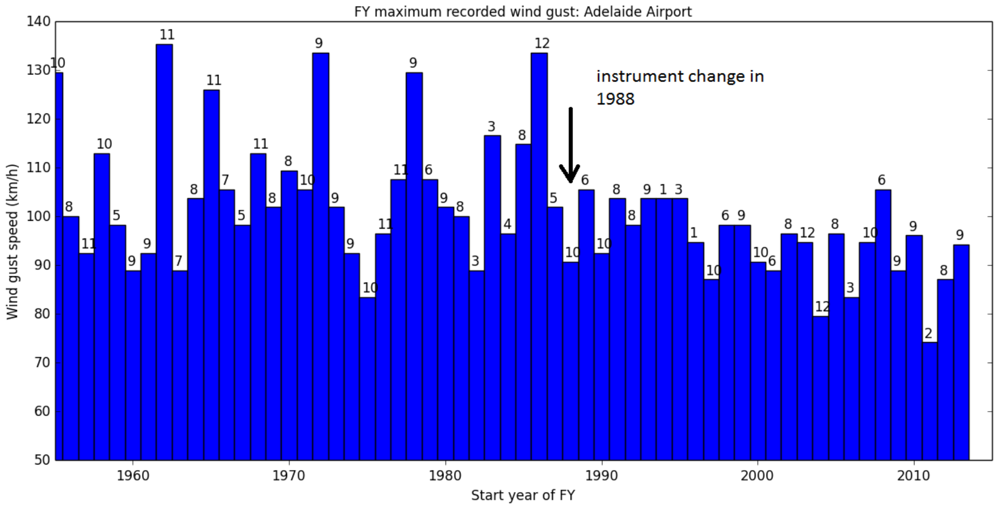


Figure 6.1-3 Maximum daily wind run per FY for Adelaide Airport (month of occurrence is shown over the bar plot)

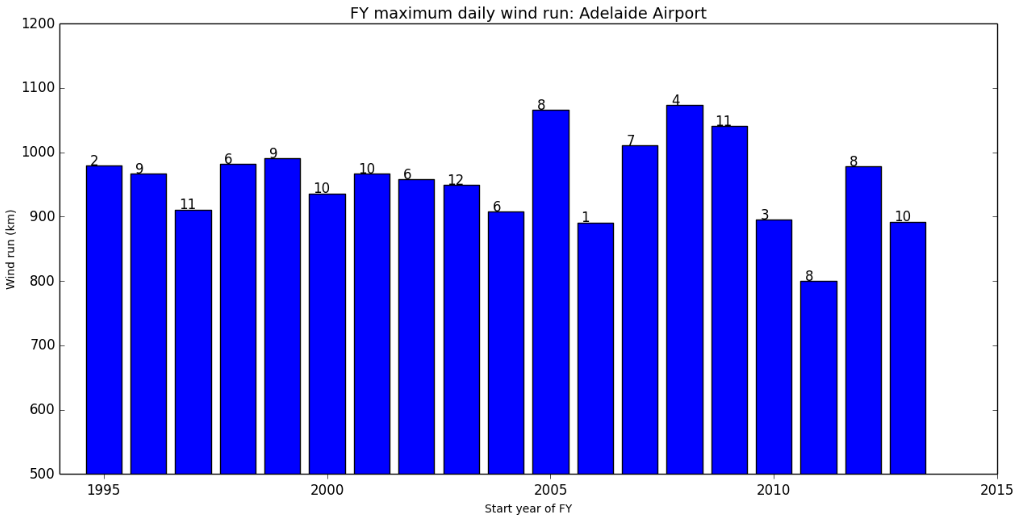


Figure 6.1-4 Maximum recorded wind gust per FY for Adelaide Airport (month of occurrence is shown over the bar plot)

It is noteworthy that most extreme winds occur in the months June to October, with strong clustering around August to October.

Taking the change in instrument at Adelaide Airport into consideration maximum wind gusts still decline at that site from the late 1980's onwards. Wind records at Adelaide Hills weather stations are too short to support this.

Highest daily wind run for any FY as seen in Figure 6.1-2 and 6.1-3 show an increase in variability from about 2005, though records are too short to establish if this is significant or not.

In summary there is no indication of any increase in extreme wind events either in wind gusts or wind run measurements from any station in the analysis, with if anything a slight decline occurring.

6.2 Extreme heat and impact on tree die off

The contribution of climate change to tree die off has been a subject of recent research. The Millennium Drought from 1996 -2009 saw large areas of tree die off occurring in parts of southern Australia in response to hot and drier conditions. Mitchell et al 2014 examined climatic thresholds impacting trees, establishing that periods of 3 days above the 90th percentile maximum temperature as being a necessary condition for tree die off episodes.

With increases in temperature and heat extremes in recent decades demonstrated, as seen in Sections 2 and 3 of this report, further analysis was done of temperature records in the Adelaide and Port Lincoln area using the criteria of Mitchell et al 2014 to seek to identify any significant trends or variability.

The Bureau of Meteorology's Australian Climate Observations Reference Network – Surface Air Temperature data is a dataset using station data from long term sites that has been checked for inhomogeneities from instrument or site changes that might cause spurious trends in temperatures (see http://www.bom.gov.au/climate/change/acorn-sat/)

Daily maximum temperatures from the Bureau of Meteorology's ACORN-SAT dataset were analysed for frequency of such events (3 days or more > 90th percentile maximum temperatures), duration (longest consecutive run per FY of days >90th percentile maximum temperature), and a measure of intensity of these heat extremes (the difference from the 90th percentile maximum temperature averaged across the longest run in any FY). Figures 6.2-1 to 6.2-3 below show results for Adelaide Airport, Nuriootpa and Port Adelaide.

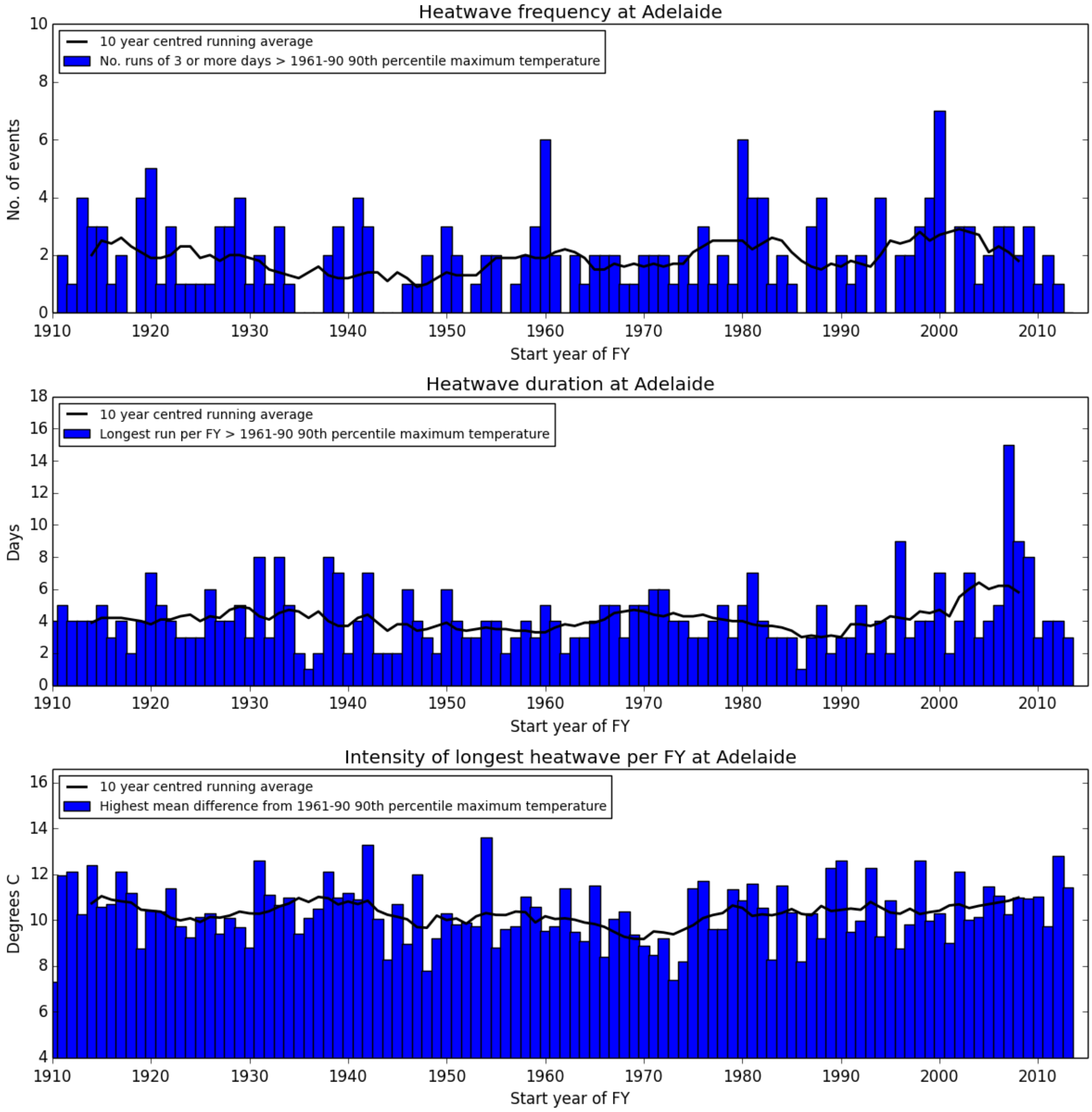


Figure 6.2-1 Heat event frequency, duration and intensity per FY for Adelaide

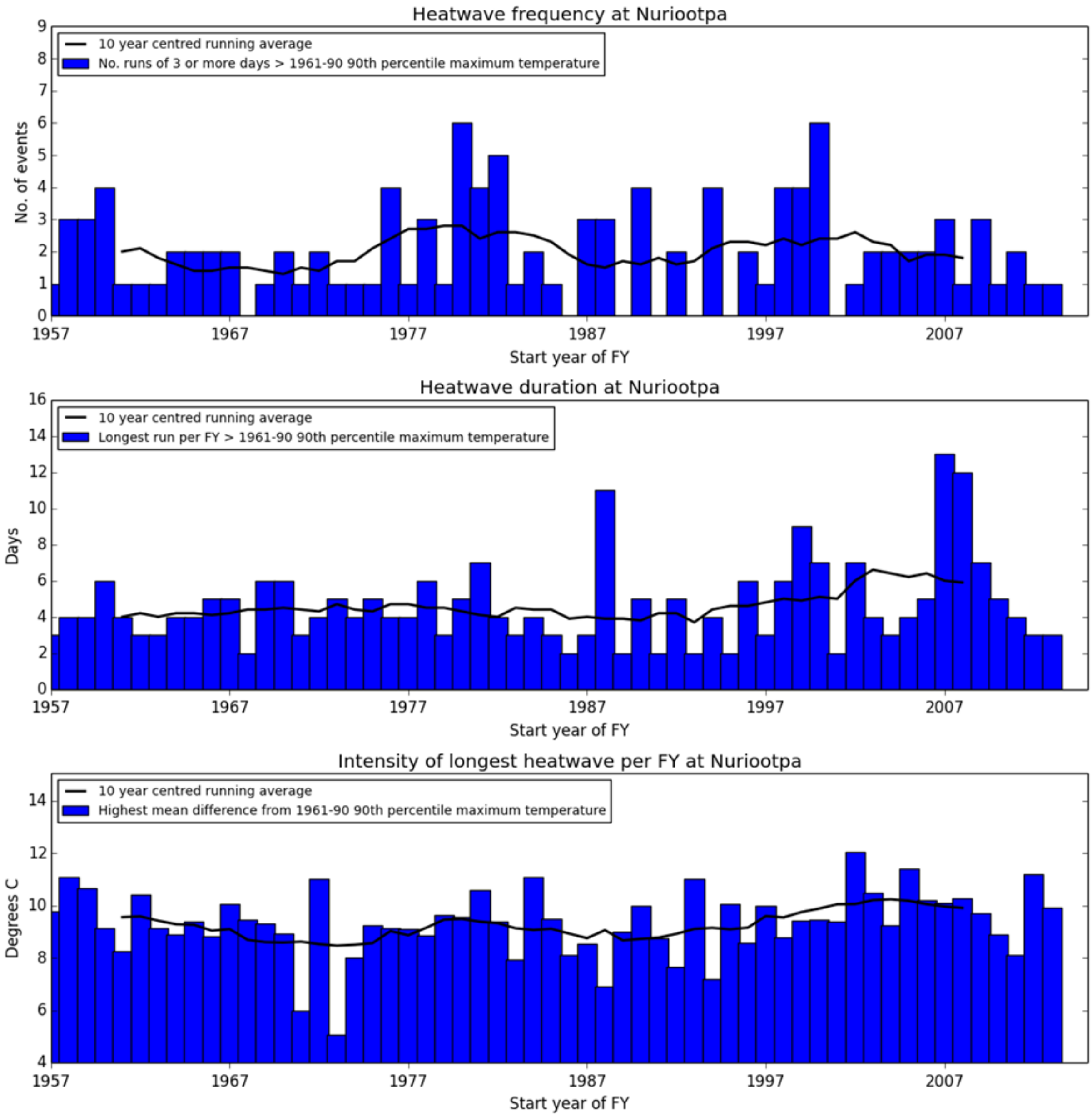


Figure 6.2-2 Heat event frequency, duration and intensity per FY for Nuriootpa

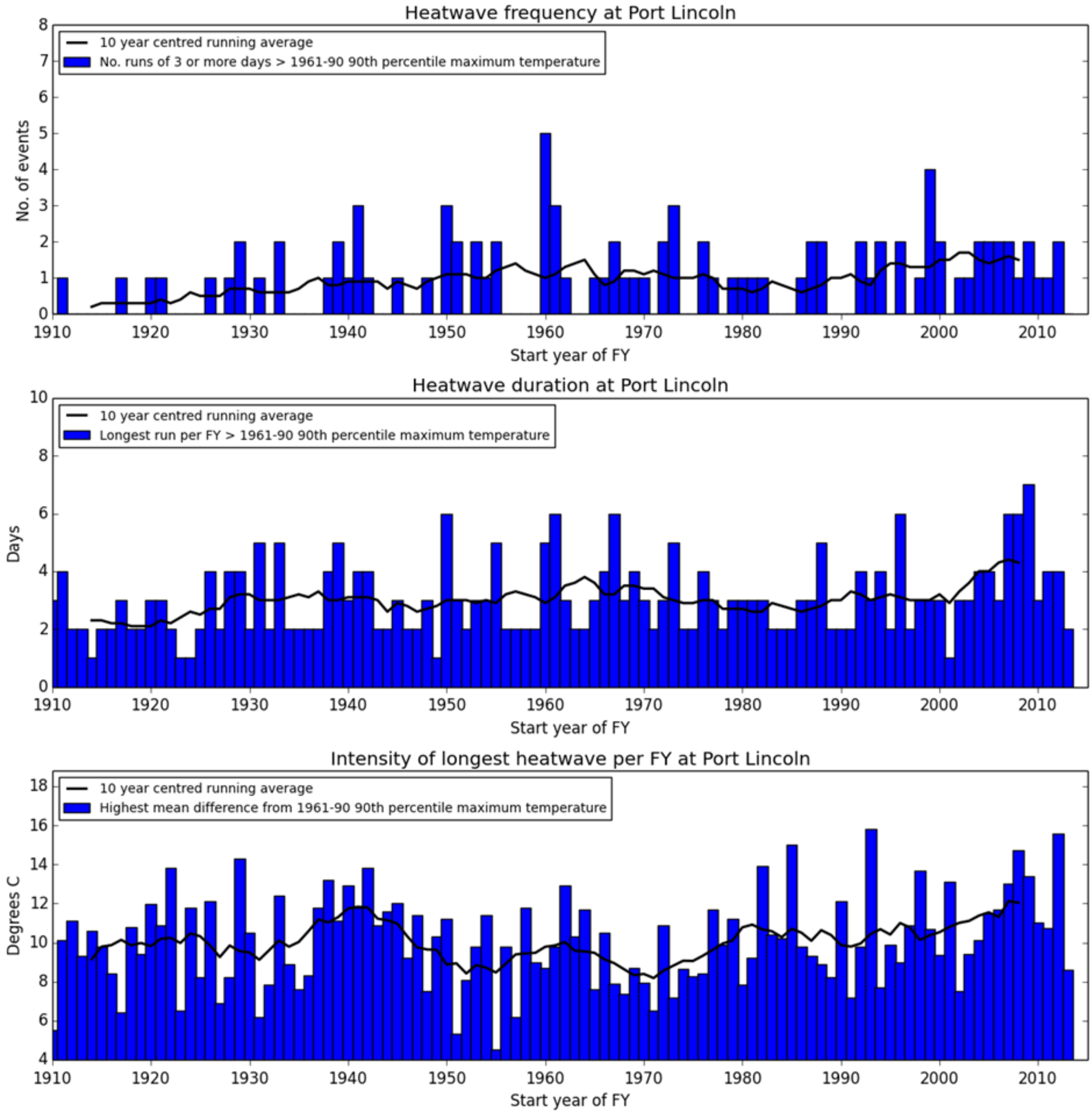


Figure 6.2-3 Heat event frequency, duration and intensity per FY for Port Lincoln

The frequency of heat extremes, seen above, shows some correlation with Interdecadal Pacific Oscillation (IPO) phase, as did mean temperature and FFDI, as seen in Sections 3 and 4. Increased heat event frequency is seen through the mid 1970's to the late 1990's at all sites matching the positive phase of the IPO, with a subsequent decrease in frequency in the 2000's on in the negative IPO phase.

All sites show relatively stable levels of heat event duration up until ~1990, when heat event duration increases significantly, though the most recent years see events of lesser duration. The intensity of the longest heat event in any FY is relatively stable through the record at Adelaide and Nuriootpa, with an increasing trend since ~1980 at Port Lincoln.

From the above, while there is no indication of increases in extreme wind events in areas relevant for SAPN power lines, there appears to be an increase since the late 1990's in the duration of heat events that might impact tree die off, so that when wind events do occur prior hot conditions may have led to increased heat stress of trees and lead to more material being available to be blown onto power lines. Further detailed analysis is beyond the scope of this report but warrants further investigation.

Glossary

ACORN-SAT	Australian Climate Observations Reference Network – Surface Air Temperature
AWAP	Australian Water Availability Program
SAPN	South Australian Power Networks
FFDI	Forest Fire Danger Index
IOD	Indian Ocean Dipole
ENSO	El Niño Southern Oscillation
IPO	Interdecadal Pacific Oscillation
METAR	An aviation weather observing format used by the Bureau of Meteorology
SA	South Australia
JASO	July August September October
NDJFM	November December January February March
FY	Financial Year (ie July to June)
ADT	Average Daily Temperature (the average of the maximum and minimum temperature on any day)
AMO	Aerodrome Meteorological Office
POAMA	Predictive Ocean Atmosphere Model for Australia
NE	North east
SOI	Southern Oscillation Index

References

Australian Academy of Science (2010) The science of climate change
http://www.science.org.au/publications/science-climate-change-questions-and-answers

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
http://images.smh.com.au/file/2013/09/14/4747251/fires1973.pdf

CSIRO and Bureau of Meteorology (2007). Climate Change in Australia, Technical Report, Australia.

Mitchell P, O'Grady A, Hayes K, Pinkard E (2014) Ecology and Evolution 4 (7) 1088-1101
http://onlinelibrary.wiley.com/doi/10.1002/ece3.1008/pdf

Power et al (1999) Climate Dynamics 15, 319–324
http://link.springer.com/journal/382/15/5/page/1

State of the Climate (2014). Bureau of Meteorology http://www.bom.gov.au/state-of-the-climate/

Troccoli A., Muller K., Coppin P., Davy R., Russell C. & Hirsch, A. (2012). Long-Term Wind Speed Trends over Australia. Journal of Climate, 25, 170-183.
http://journals.ametsoc.org/doi/full/10.1175/2011JCLI4198.1