Australian Government
Bureau of Meteorology

Severe thunderstorm and tornado outbreak South Australia 28 September 2016

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1 Executive Summary

One of the most significant severe thunderstorm outbreaks in recent decades impacted central and eastern districts of South Australia during the afternoon and evening on 28 September 2016. Multiple supercell thunderstorms produced damaging to destructive wind gusts, including at least seven tornadoes, very large hailstones and locally intense rainfall. These supercell thunderstorms and tornadoes impacted the South Australian power network, contributing to a state-wide power outage.

The severity of the thunderstorms was aided by an intense and powerful mid-latitude cyclone (low pressure system), which intensified over the Great Australian Bight on 28 September and directly impacted the state on 29 September.

The severe thunderstorm and tornado outbreak described in this report was the initial phase in a week of severe weather in South Australia. This followed a tumultuous winter and spring where wetter and windier that average conditions had already stretched the State Emergency Service which had already turned out to more jobs than the previous year. Winds on 29 September reached storm force over coastal waters, generating damaging wave action and a significant storm surge in Spencer Gulf. Persistent heavy rain over the Mount Lofty and Flinders Ranges led to flooding impacts, including widespread riverine flooding which continued through to 2 October. A series of fronts associated with a second low pressure system brought further bursts of severe winds and moderate to heavy rain during 2-4 October, which led to renewed flooding.

The impacts arising from the range of weather hazards experienced during the period 28 September to 5 October 2016 will be documented in three reports.

This report focusses on the severe thunderstorm and tornado outbreak on 28 September. The meteorology is described at various scales, from the broad scale antecedent conditions to the synoptic and mesoscale development of supercell thunderstorms and tornadoes. An assessment of ground damage, track length and strength is provided for four of the seven tornadoes, including the impact on power network infrastructure.
Two additional reports are in preparation. These reports will cover the significant storm surge on 29 September 2016 and the widespread floods, which were the most significant in South Australia since November 2005. The flood report will include performance assessments of rain and flood forecasts including forecast and warning systems. The role of the meteorologist embedded within emergency services will also be examined.

The Bureau's engagement with emergency services has been reinforced since 2015 when South Australia's fire and emergency sector secured the services of an embedded meteorologist under contract from the Bureau of Meteorology. The embedded meteorologist rapidly developed a trusted relationship with the Country Fire Service during the Sampson Flat and Pinery Fires, with the State Emergency Service deeply engaged throughout the wet and windy winter and spring in the lead up to this event. Initial indications of a significant weather system with potential severe wind and rain impacts were provided to the State Emergency Service on Friday 22 September. Escalating confidence in the historical significance of the approaching weather system on Monday 26 September provided the SES a firm platform for pre-emptive activation strategies.

2 Introduction

One of the most significant severe thunderstorm outbreaks in recent decades impacted central and eastern districts of South Australia during the afternoon and evening on 28 September 2016. Multiple supercell thunderstorms produced damaging to destructive wind gusts, including at least seven tornadoes, very large hailstones and locally intense rainfall. These supercell thunderstorms and tornadoes impacted the South Australian power network, contributing to a state-wide power outage.

The severity of the thunderstorms was aided by an intense and powerful mid-latitude cyclone (low pressure system), which intensified over the Great Australian Bight on 28 September and directly impacted the state on 29 September.

This report focusses on the severe thunderstorm and tornado outbreak on 28 September. The meteorology is described at several scales, from the broad scale antecedent conditions to the synoptic and mesoscale development of the supercell thunderstorms and tornadoes. Weather radar and satellite data have been analysed and integrated with information gathered from an inspection of damage by skilled meteorologists on 6 October. An assessment of damage characteristics, track length and strength is provided for four of the seven tornadoes, including the impact on power network infrastructure. Warnings provided on 28 September are described.

3 Meteorology

3.1 Antecedent Conditions

Early in 2016 a weak negative Indian Ocean Dipole (IOD) became established across the Indian Ocean, with a subsequent rapid strengthening during the early part of winter to be at its lowest value on record during July. The negative IOD weakened slightly during August and September but still remained strongly negative. Negative IOD events result from an intensification of westerly winds along the equator, which allows warmer waters to concentrate near Australia. This can be seen in Figure 1, which shows very much above average to highest on record sea surface temperatures (SST) for the Timor Sea and the Indian Ocean south of Java for winter 2016.

Negative IOD events typically result in above average winter–spring rainfall over parts of southern Australia as the warmer waters off northwest Australia provide increased available moisture to weather systems crossing the country.

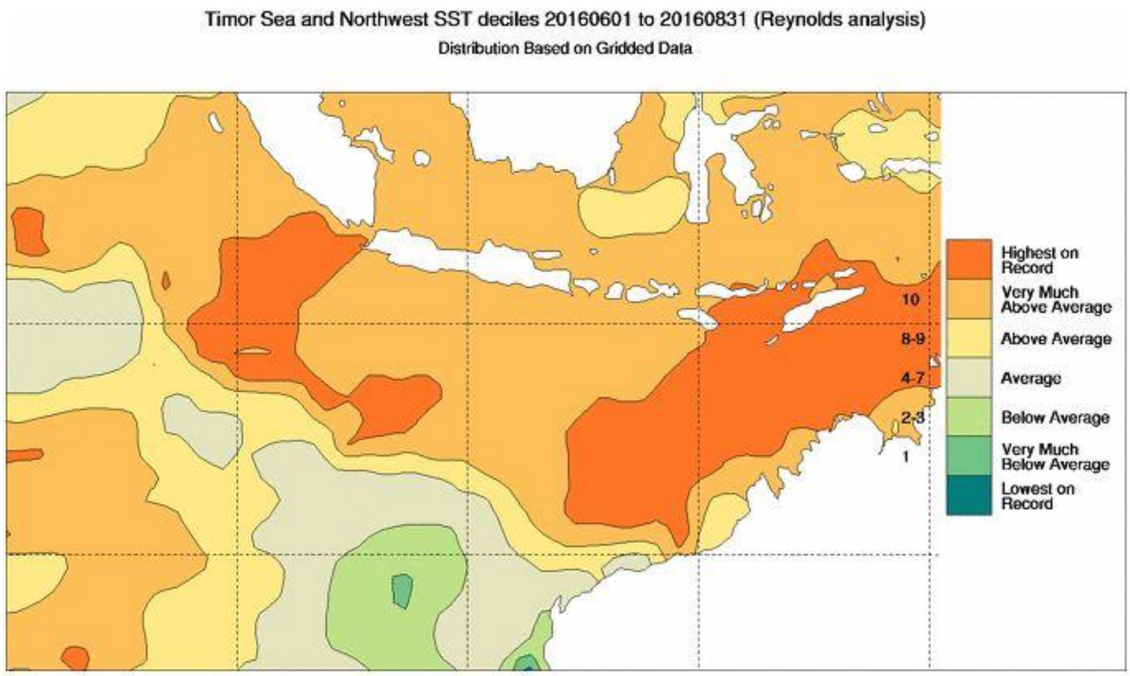

Figure 1: *Sea surface temperature (SST) deciles for the Timor Sea and the Indian Ocean south of Java for winter 2016 (1 June to 31 August).*

During winter 2016, the above average SST northwest of Australia provided increased moisture flow across the continent, which resulted in numerous rain bearing northwest cloud bands. The

interaction of this northern moisture with many mid-latitude frontal systems resulted in winter 2016 being the second wettest winter on record for Australia (see Figure 2).

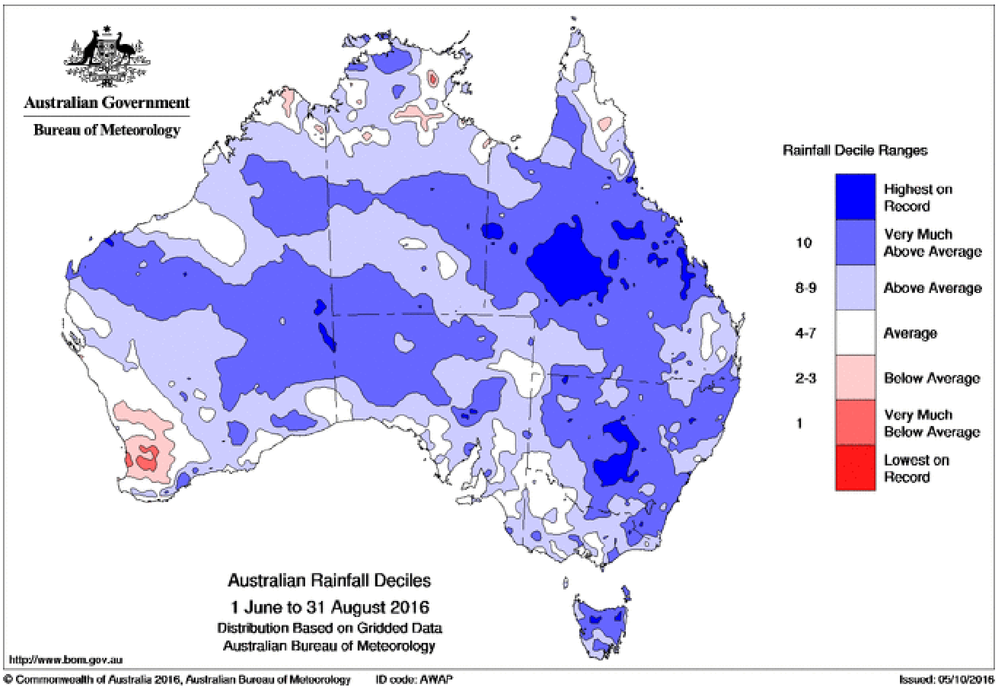

Figure 2: Rainfall deciles for Australia for winter 2016 (1 June to 31 August).

The abnormally high rainfall in the preceding months produced root zone soil moisture values (top 1 metre) which were highest on record for much of September. This can be seen in Figure 3, which shows a large portion of the Northern Territory, inland Queensland, inland New South Wales and northeast inland South Australia had highest on record zone soil moisture the day prior to the event.

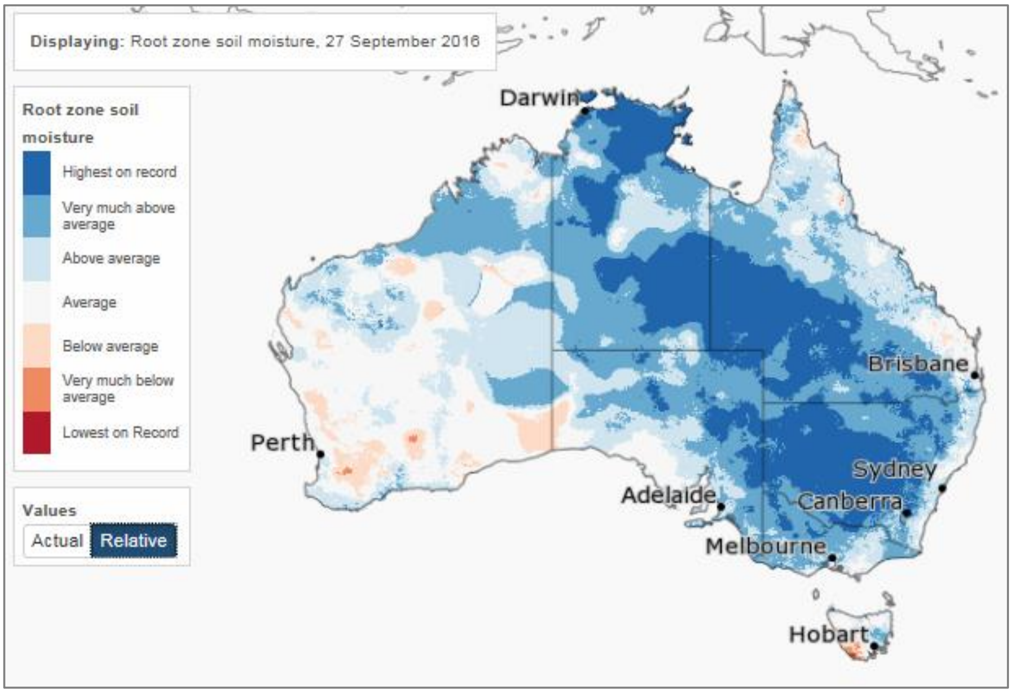

Figure 3: *Root zone soil moisture variation from average (top 1 metre) for 27 September 2016.*

Madden-Julian Oscillation (MJO) phase 5 is associated with enhanced westerly wind flows across the north of the continent and is often associated with increased cloudiness and rainfall through the tropical parts of the country.

In the week prior and during this event, the MJO was active in phase 5. This is likely to have reinforced the effects of the negative IOD, contributing to the high moisture flow across the north and centre of Australia towards South Australia.

3.2 Synoptic Scale Development

In the days prior to 28 September, a highly dynamic Rossby wave pattern resulted in the polar jet stream developing a strong meridional pattern. An upper ridge developed over the southern Indian Ocean and an upper level trough amplified over the Southern Ocean and southern Western Australia. In response to the amplifying upper level trough a surface low pressure system developed south of Albany, Western Australia on 27 September.

During the morning on 28 September the upper trough became negatively tilted near the Western Australia and South Australia border, and began to 'cut off' from the polar jet to the south as a breaking Rossby wave. The cut off upper trough resulted in a transfer of vorticity to the surface, with subsequent explosive cyclogenesis of the surface low pressure system. The central pressure fell 23 hPa in 24 hours to be 973 hPa south of the Bight by 4 pm CST on 28 September.

The low pressure system also generated a north-south oriented cold front, which entered the west of South Australia early on 28 September. The cold front tracked east at about 85 km/h to be near Woomera to Port Augusta to Kangaroo Island by 4 pm, then Moomba to Broken Hill to Mount Gambier by 10 pm (see Figure 4).

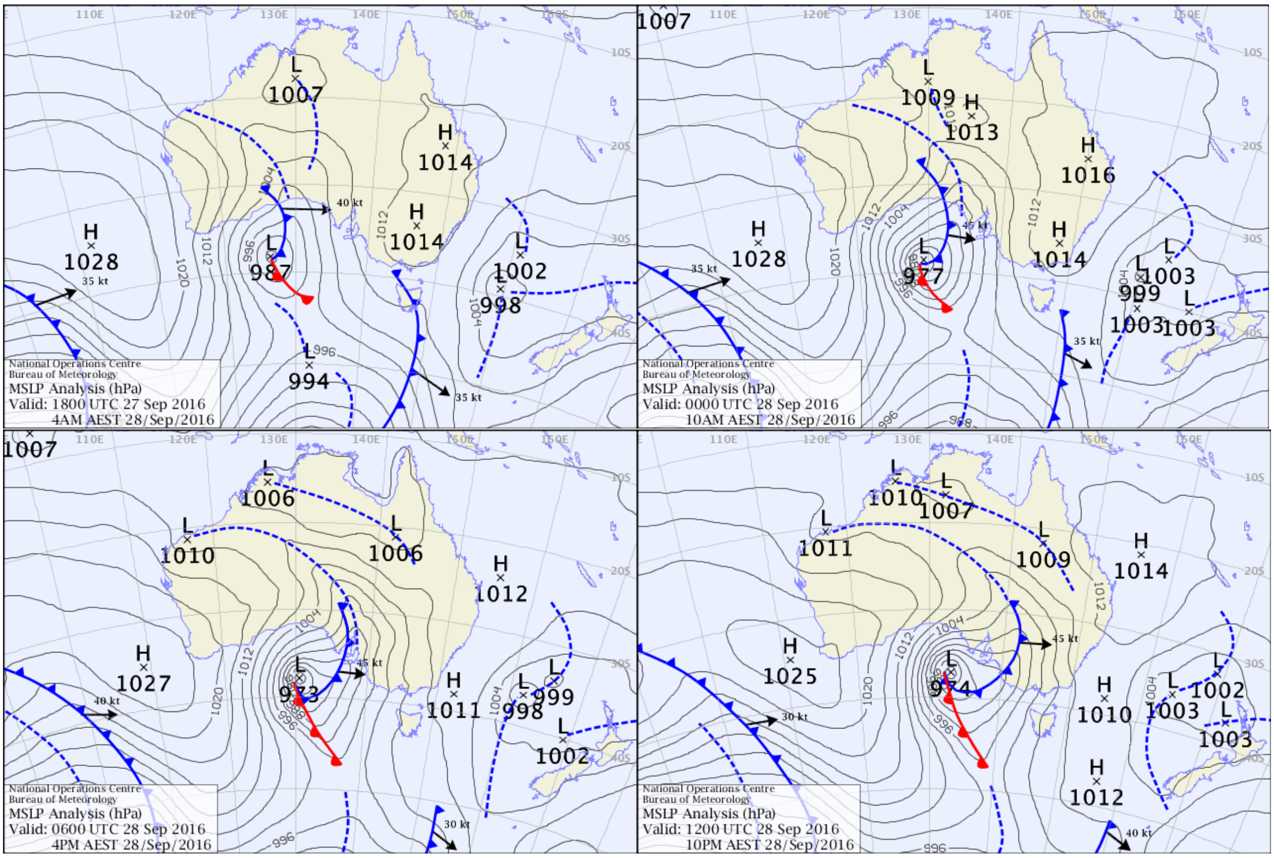

Figure 4: *Synoptic mean sea level pressure charts for 28 September 2016. from top left to bottom right - 3:30 am (CST), 9:30 am (CST), 3:30 pm (CST) and 9:30 pm (CST).*

3.3 Mesoscale Thunderstorm Development

The four key ingredients for severe thunderstorm development are moisture, instability, lift and wind shear. During the afternoon on 28 September these ingredients combined on and ahead of the front.

Moisture:

In the days preceding 28 September, rain across central Australia reinforced the already wet surface and soil conditions over inland areas. The resulting high humidity air over the Simpson Desert was advected south into central and eastern districts of South Australia by strong northerly pre-frontal winds.

In the early hours on 28 September, middle level thunderstorms developed over the North West Pastoral and Eyre Peninsula and moved southeast across central and eastern districts as a thundery rain band during the late morning and early afternoon. This increased moisture levels over central parts of South Australia where thunderstorms later developed. For example, the surface dew point at Whyalla increased from 6°C at 9 am CST to around 17°C by early afternoon (see Figure 5).

The increased moisture led to low cloud bases, with lifting condensation levels (LCL) of around 400 to 800 m above ground level. Such low LCL increase the potential for tornado development. Precipitable water (PW) values were around 30 mm, significantly higher than the long term September average of 14 mm. Elevated PW values increase the potential for thunderstorms to produce heavy rainfall conducive to flash flooding.

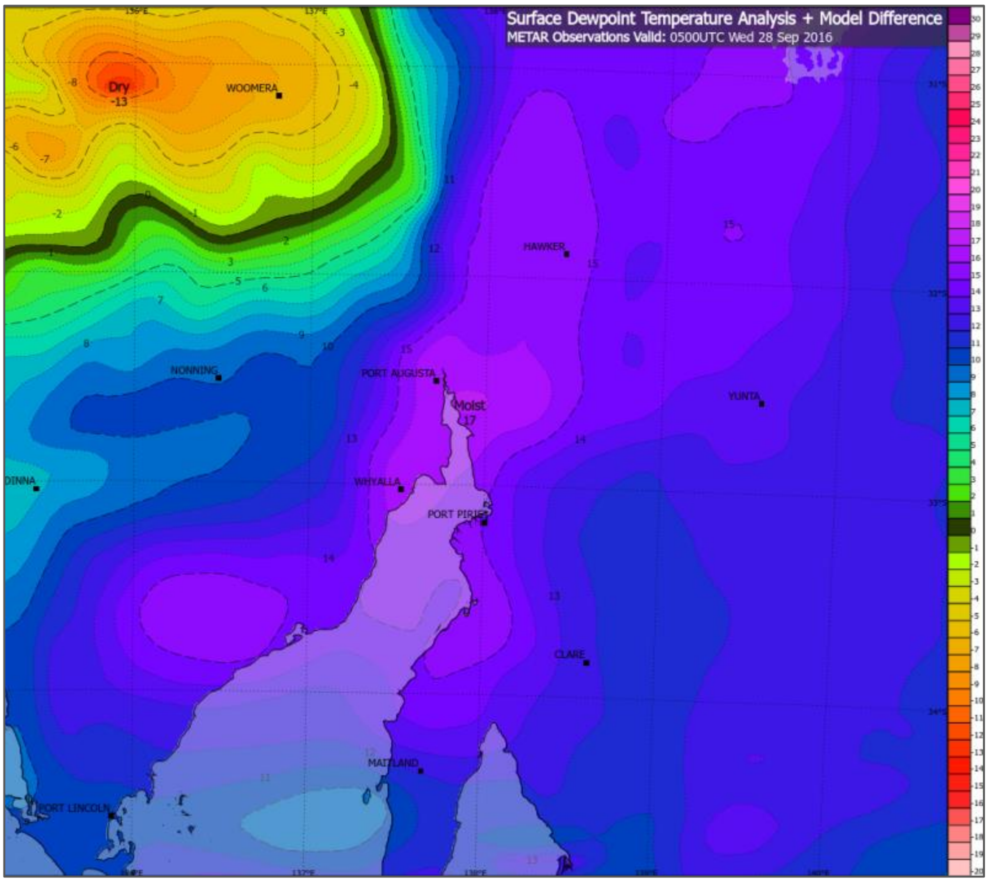

Figure 5: *Surface dewpoint temperature observation analysis at 2:30 pm CST 28 September, showing the high moisture levels ahead of the front.*

Instability:

Clear skies following the thundery rain band led to strong surface heating. The combination of warm moist surface conditions beneath a relatively cold upper atmosphere associated with the upper trough, resulted in a highly unstable atmosphere. In the region ahead of the front, convective available potential energy (CAPE) values were around 1800 J/kg, with surface to 500 hPa lifted indices (LI) as low as -8°C (see Figures 6 and 7). Such large values of CAPE combined with the relatively low freezing level increased the potential for large hail.

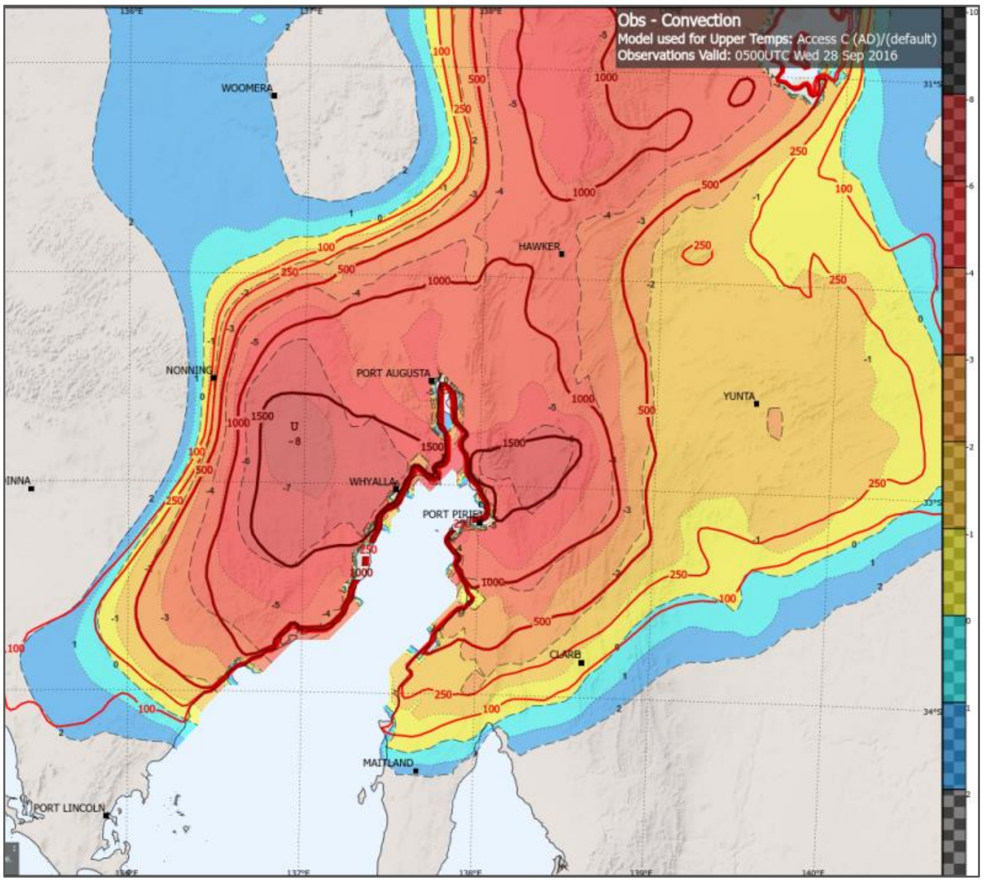

***Figure 6*:** *CAPE (red contours) and LI (shaded) analysis 2:30 pm CST, showing the highly unstable environment ahead of the front.*

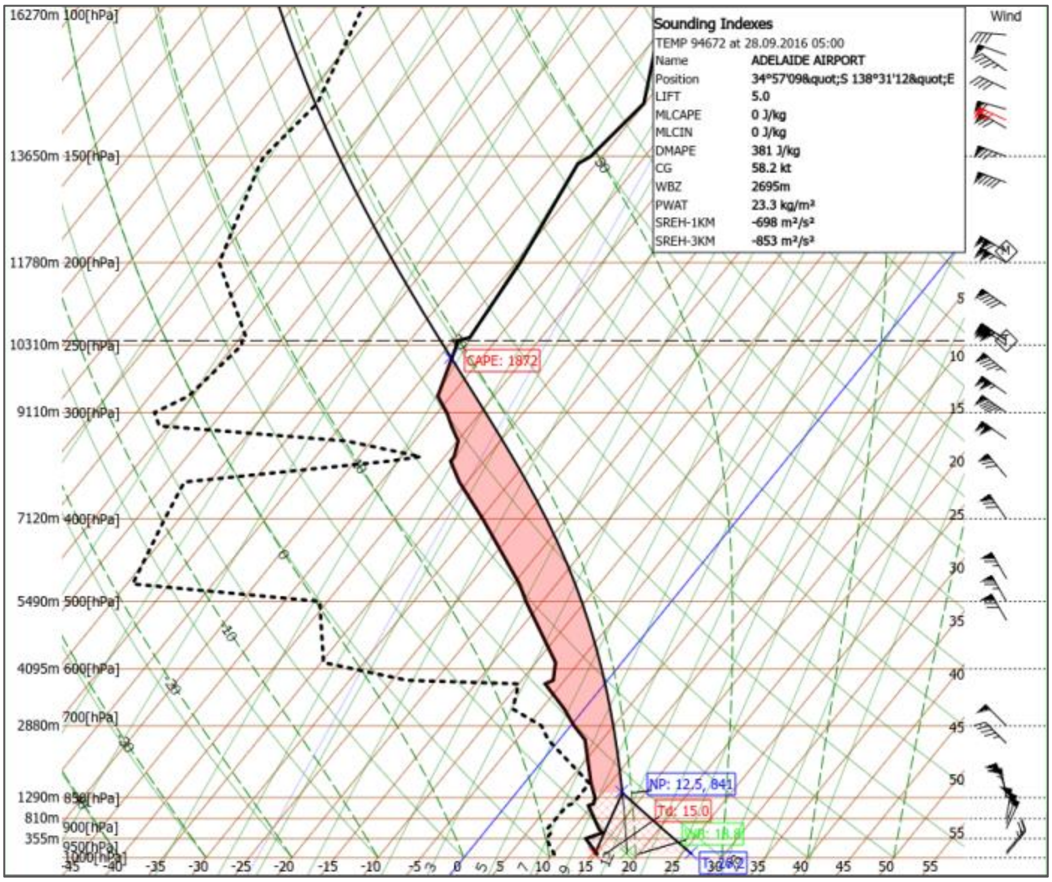

Figure 7: *Aerological diagram for Adelaide Airport at 2:30 pm CST, modified with temperature and dewpoint temperature observations from Port Pirie Automatic Weather Station (AWS).*

Lift:

The main lifting mechanism was the exceptionally strong convergence along the cold front, produced by strong to gale force northeast winds immediately ahead of the front which shifted westerly at similar speeds behind the front. Density related uplift was enhanced by the large difference in mixing ratio (4-5 g/kg) across the frontal boundary. The strong surface heating immediately ahead of the cold front and local topography across the region of thunderstorm development would have also contributed to the lifting mechanism.

Wind shear:

The vertical structure of wind in the thunderstorm environment is a critical element for thunderstorm organisation, particularly the development of supercell thunderstorms. Supercell thunderstorms are defined by the presence of a deep rotating updraft (mesocyclone) within the thunderstorm. Supercell thunderstorms are far more likely to produce severe weather phenomena including tornadoes than ordinary thunderstorms.

Deep layer (0-6 km) bulk wind shear values in excess of 35-40 knots are commonly associated with supercells. Bulk wind shear values on 28 September were 40-50 knots. The steering flow indicated thunderstorm motion from the northwest to the southeast.

Helicity describes low level wind speed and directional shear and is a key predictor for the development of supercell thunderstorms and tornadoes. The upper air wind profile at Adelaide Airport at 2:30 pm CST and the surface wind observations at Clare AWS were used to calculate storm relative helicity (SRH). SRH from 0 to 3 km was approximately -850 m^2/s^2 and from 0 to 1 km was approximately -700 m^2/s^2. These values are extreme considering 0 to 1 km values as low as +/-100 m^2/s^2 indicate an increased likelihood of supercells and tornadoes. These extreme SRH values can be inferred from the 'looping' hodograph shown in Figure 8.

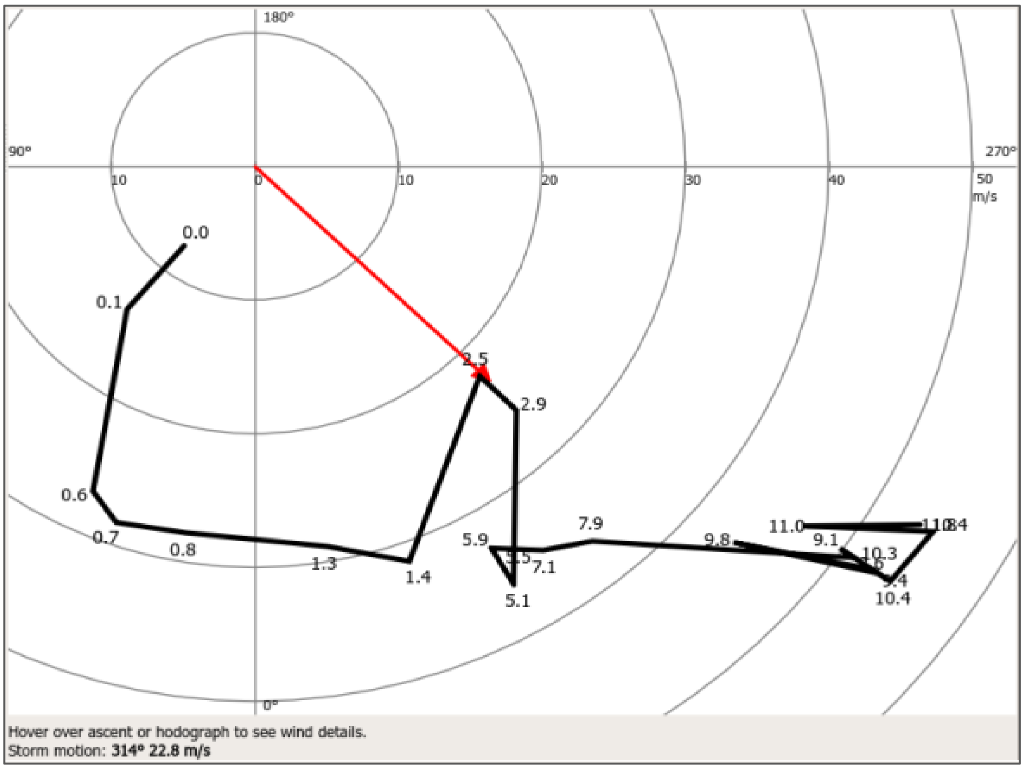

Figure 8: *Hodograph based on the upper winds from Adelaide Airport at 2:30 pm CST and surface wind observations from Clare AWS. The looping shape of the wind shear profile (black line) indicates extreme low level SRH, which is favourable for tornado formation. The storm motion vector (red arrow) is northwest at 82 km/h.*

3.4 Radar and Satellite Evidence

Radar data is a critical tool used by operational forecasters to determine the real-time location, severity and track of thunderstorms. Volumetric reflectivity and velocity are primary data types used to identify severe thunderstorm signatures. On 28 September the Buckland Park Doppler Radar was used to monitor supercell thunderstorms. As the thunderstorms moved into northern Yorke Peninsula and the Mid North, the proximity to the radar enabled a detailed analysis of severity. Unfortunately the lack of radar coverage over Eyre Peninsula and the Flinders district precluded a detailed radar analysis of the thunderstorms over these areas.

Figure 9 shows radar reflectivity scans at 0.5° (left) and 1.8° (right) of the supercell thunderstorm responsible for the Blyth tornado (see Tornado Damage Assessment). The scans were taken

between 03:31 pm and 03:32 pm, which is around the approximate start time of the tornado. The top and bottom panels show the plan position indicator (PPI) and the range height indicator (RHI) views respectively. Severe thunderstorm radar signatures evident include: (1) Bounded weak echo region (BEWR) - local minimum in radar reflectivity as updraft carries precipitation aloft. (2) Hook echo – heavy precipitation wrapping around the low level mesocyclone creating a hooked shaped pendant. (3) Elevated core with extreme maximum reflectivity (74.5 dBZ at 1250 m) – heaviest precipitation and hail held aloft by strong updraft. (4) Echo top displacement – storm top displaced from the core to be above the BWER where the strongest updraft is located. (5) Tight low level reflectivity gradient – strong updraft and downdraft.

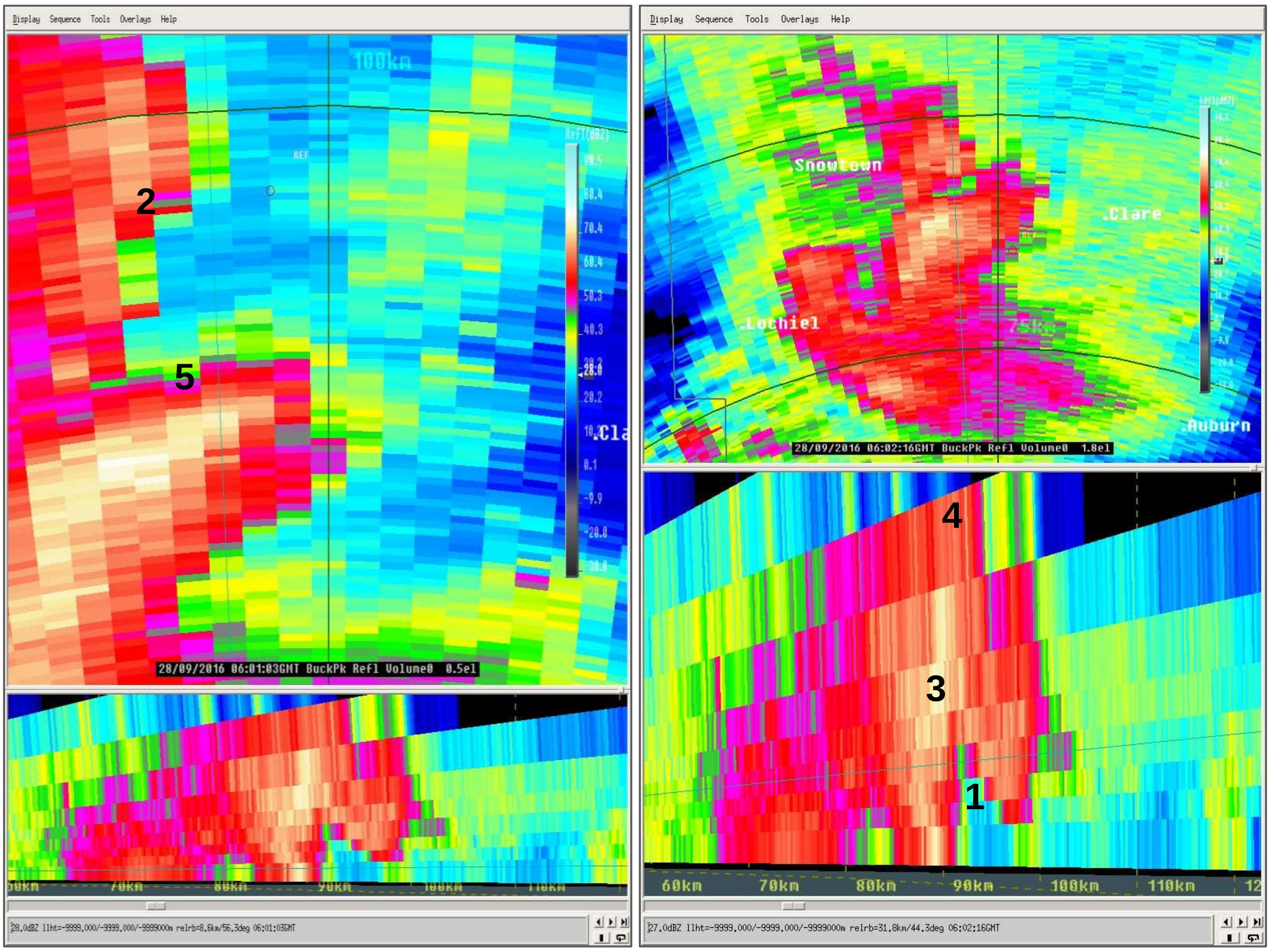

Figure 9: *Buckland Park Radar reflectivity scans at 0.5°, 03:31 pm (left) and 1.8°, 03:32 pm (right) of the supercell thunderstorm responsible for the Blyth tornado. Numbers indicate severe thunderstorm radar signatures; (1) bounded weak echo region (BEWR), (2) hook echo, (3) elevated core with extreme maximum reflectivity (74.5 dBZ at 1250 m), (4) echo top displacement, and (5) tight low level reflectivity gradient in the updraft/downdraft boundary.*

To identify and diagnose the strength of the Blyth supercell mesocyclone on radar, we analysed the velocity data through the vertical extent of the thunderstorm. An idealised radial velocity signature of a mesocyclone is shown in Figure 10. The rotational velocity strength is obtained by adding the magnitudes of the maximum inbound and outbound velocities, then dividing by 2. It should be noted that some inbound velocities analysed were aliased.

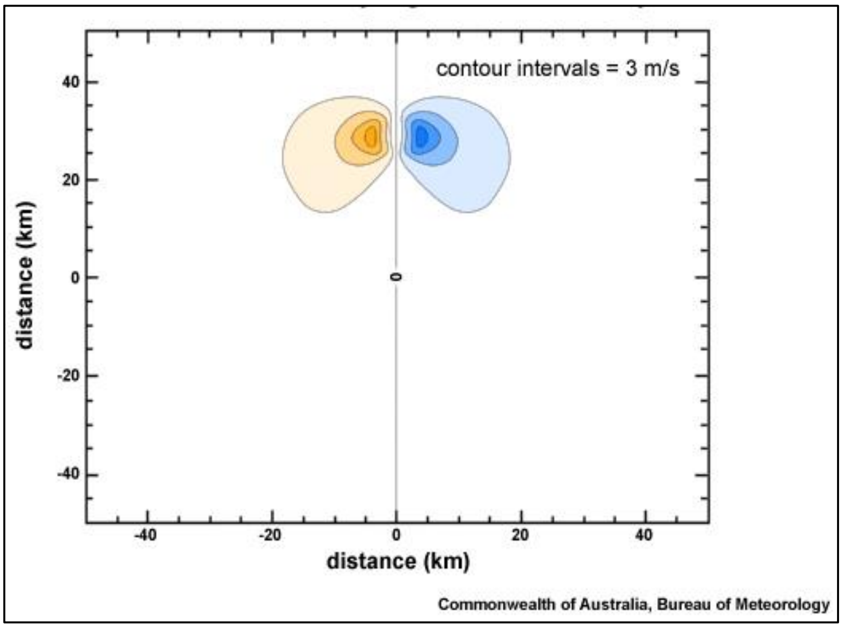

Figure 10: *Idealised radial velocity signature of a mesocyclone where blue is inbound and yellow outbound.*

Figure 11 shows the 0.5° velocity scan also taken at 03:32 pm. The low level mesocyclone (circled in black) shows a peak rotational velocity of 32 m/s (62 knots) in the vicinity of the hook echo at approximately 1400 m AGL. According to Smith, B et al (2015)[1] a peak 0.5° rotational velocity of 60 – 65 knots gives a 55 % – 60 % conditional probability of an EF2+ occurrence. This is consistent with the damage assessed rating (see Tornado Damage Assessment).

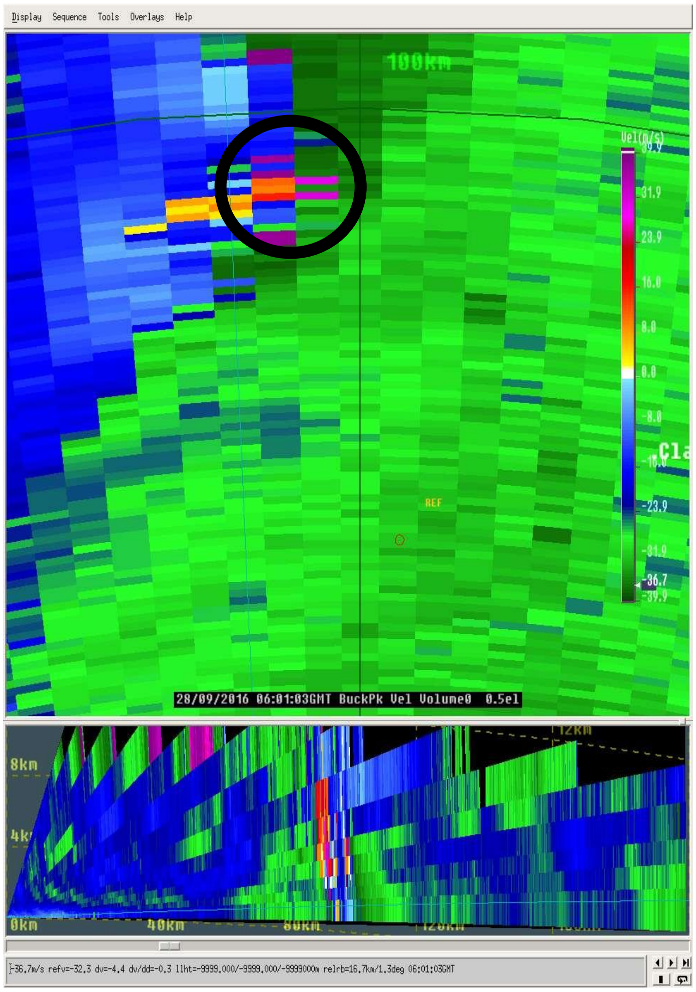

***Figure 11:** Buckland Park Doppler Radar 0.5° velocity scan at 03:31 pm of the supercell thunderstorm responsible for the Blyth tornado. The peak rotational velocity is 32 m/s (circled in black) at 1400m AGL.*

Figures 51 and 52 in Appendix A show the velocity scans for the 1.3° (approx. 2800 m) - 3.1° (approx. 5600 m) scans taken between 03:31 pm and 03:03 pm at a range of around 100 km. The average peak rotational velocity of these 4 scans of the mesocyclone through the 2800 m in depth is 28.2 m/s (54 knots), correlating to a very strong mid-level mesocyclone.

In areas of poor or no radar coverage satellite data is the primary tool used by operational forecasters to determine the real-time location, severity and track of thunderstorms. Images from the Japanese weather satellite Himawari-8 were utilised on September 28.

Figure 12 shows a multilayered Himawari-8 satellite image from 03:40 pm. This product uses high resolution visible imagery, blended with enhanced infrared (IR) imagery. The IR enhancement applies temperature colour ranges to the cold end of the scale, highlighting deep convection. Several severe thunderstorm satellite signatures are evident on the supercells responsible for the tornadoes (refer Tornado Damage Assessment). These signatures include, overshooting tops (strong updraft causing cloud to protrude above the equilibrium level of the anvil), back sheared anvils (strong updraft causing the anvil to spread upwind) enhanced-v (cold anvil spreading around the overshooting top) warm wake (depressed area downwind of the overshooting top).

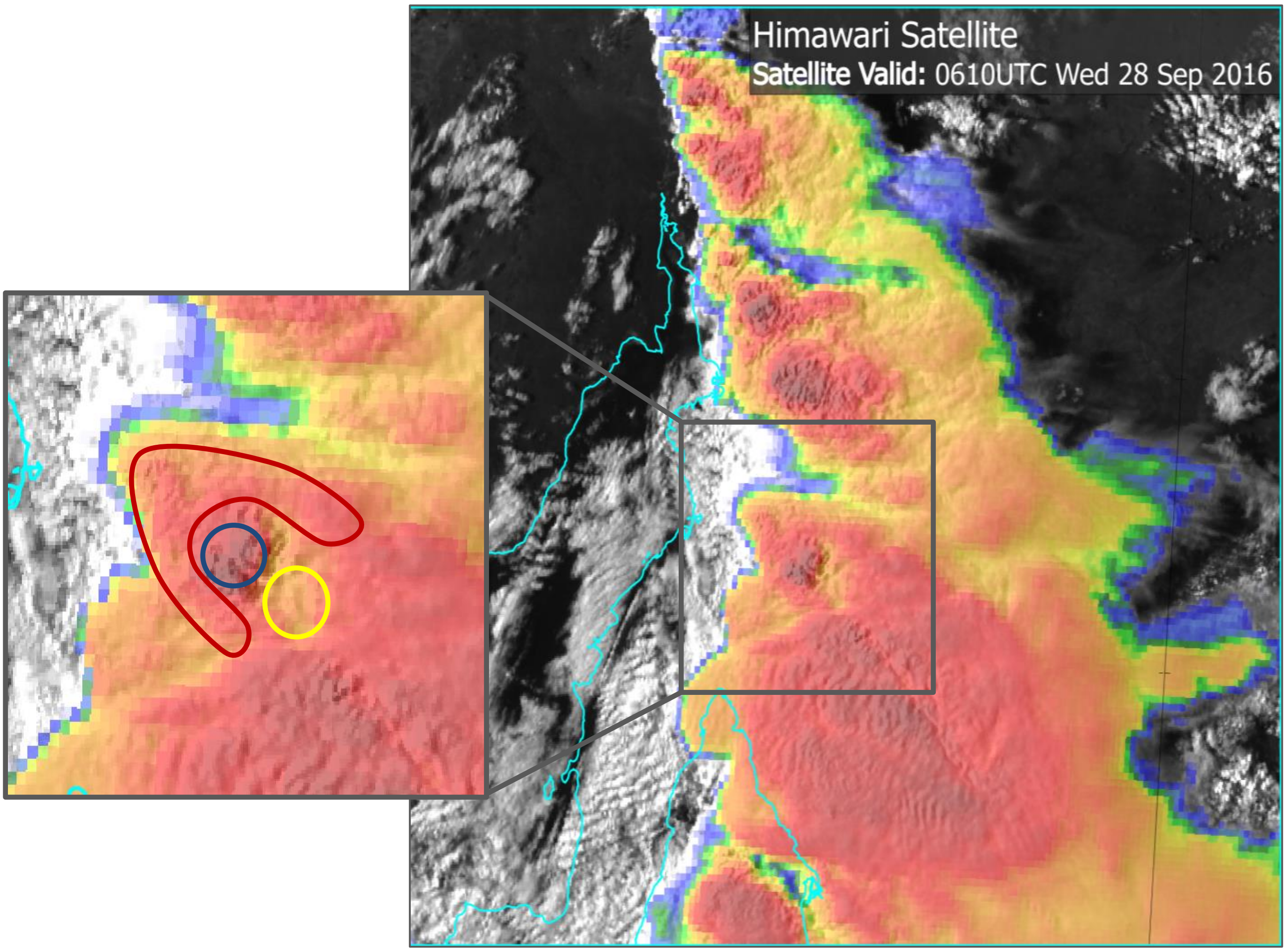

Figure 12: *Multilayered Himawari-8 satellite image from 03:40 pm showing various severe thunderstorm signatures. The subset shows the supercell responsible for the Blyth tornado with the overshooting top (blue circle), enhanced-v including the back sheared anvil (red line) and warm wake (yellow circle).*

Complimenting radar and satellite imagery, lightning data provided by Global Position and Tracking Systems (GPATS) is a tool that can be used operationally to track and identify the relative severity of thunderstorms. Figure 13 shows the daily lightning data for 28 September.

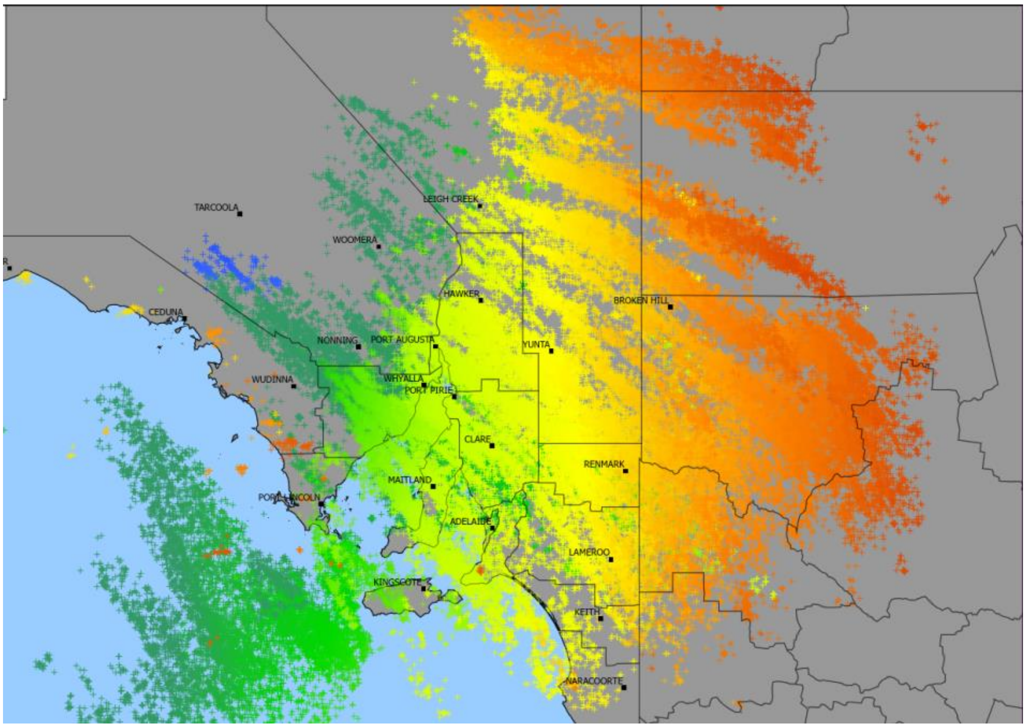

Figure 13: *24 hours of lightning data for 28 September provided by* Global Position and Tracking Systems (*GPATS). In real time lightning data can be used to assess relative severity of thunderstorms, with greater lightning frequency indicating a stronger updraft. Timing of strikes prior to midnight; Red 0 to 6 hours, Yellow 6 to 12 hours, Green 12 to 18 hours, Blue 18 to 24 hours.*

3.5 Thunderstorm Timeline - 28 September

Times are shown in Central Standard Time (CST)

11:30 am – 01:00 pm:

Thunderstorms began to develop along the frontal boundary, with the first thunderstorm cell forming near Yardea on the northern Eyre Peninsula at 11:35 am. The cells continued to develop along the frontal line tracking to the southeast ahead of the eastward progressing frontal boundary.

By 01:00 pm thunderstorms could be observed on radar along the length of the frontal boundary from Woomera in the north to Port Lincoln in the south. Two cells over Eastern Eyre Peninsula were beginning to show supercell characteristics.

01:00 pm - 02:00 pm:

These supercell thunderstorms impacted various townships across Eastern Eyre Peninsula including Kimba, Cleve, Arno Bay and Cowell before moving into Spencer Gulf shortly after 02:00 pm. There were reports of large hail (up to 5 cm at Cleve), heavy rainfall with local flash flooding and damaging winds. The highest wind gust at Cleve AWS was 87 km/h at 01:36 pm.

01:30 pm – 03:00 pm:

Thunderstorms also impacted Whyalla, Port Augusta and Woomera further north along the front with recorded AWS gusts of 83 km/h, 87 km/h and 96 km/h respectively.

02:30 pm – 03:00 pm:

Supercell thunderstorms began to impact the eastern coastline of Spencer Gulf. A wind gust of 96 km/h was recorded at Port Pirie AWS to at 02:56 pm.

- Approximately 02:50 pm there were reports (including photographic confirmation) of a tornado near Port Broughton, this was consistent with radar evidence.

03:00 pm – 03:30 pm:

The line of thunderstorms along and ahead of the front now stretches from west of Hawker in the north to the Fleurieu Peninsula in the south. Supercell thunderstorms along the line now begin to impact the Mid North and Flinders district. At Snowtown and Blyth large hail of 4-6 cm was reported (Figure 14). A wind gust of 104 km/h occurred at Snowtown AWS at 03:28 pm.

Figure 14: 4-5 cm hailstones at Blyth. Credit Zack Zweck (left) and Tanya Penna (right).

03:30 pm – 04:30 pm:

During this period 6 further tornadoes are believed to have occurred, with 4 confirmed by a damage assessment conducted on 6 October, and the remaining 2 deduced from damage reports and radar evidence.

- Approximately 03:30 pm damage consistent with a tornado occurred at Crystal Brook in the Mid North. The most significant damage appears to have occurred in the vicinity of Crystal Brook Oval where there was structural damage to sheds and sporting facilities.
- Approximately 03:35 pm a tornado starts to the northwest of Blyth in the Mid North before ending at approximately 03:50 pm to the southeast of the town (refer Tornado Damage Assessment). Damage to the Brinkworth – Templers West transmission line occurred with this tornado (see Impact on Power Transmission Network).
- Approximately 03:35 pm a tornado begins near Survey Road south of Melrose in the Flinders district. The tornado tracks approximately 23 km to the southeast before ending at approximately 04:00 pm (refer Tornado Damage Assessment).
- Approximately 03:45 pm a tornado begins near Wilmington in the Flinders district. The tornado tracks approximately 30 km to the southeast before ending at approximately 04:05 pm (refer Tornado Damage Assessment). Damage to the Davenport – Belalie and

Davenport – Mt Lock transmission lines occurred with this tornado/supercell thunderstorm (see Impact on Power Transmission Network).

- Approximately 04:00 pm at tornado begins south of Mintaro in the Mid North. The tornado tracks approximately 5 km before ending at approximately 04:05 pm (refer Tornado Damage Assessment).
- Approximately 04:00 pm damage consistent with a tornado occurred at Andrews north of Clare in the Mid North; this is consistent with radar evidence.

04:30 pm – 11:00 pm:

Thunderstorms began to merge into a squall line during the evening as the front moved through the eastern districts, stretching from the Murraylands in the south to the northern border. A wind gust of 113 km/h was recorded at Yunta at 05:50 pm as a thunderstorm on the front impacted the town. Thunderstorms eventually exited the State late in the evening.

4 Tornado Damage Assessment

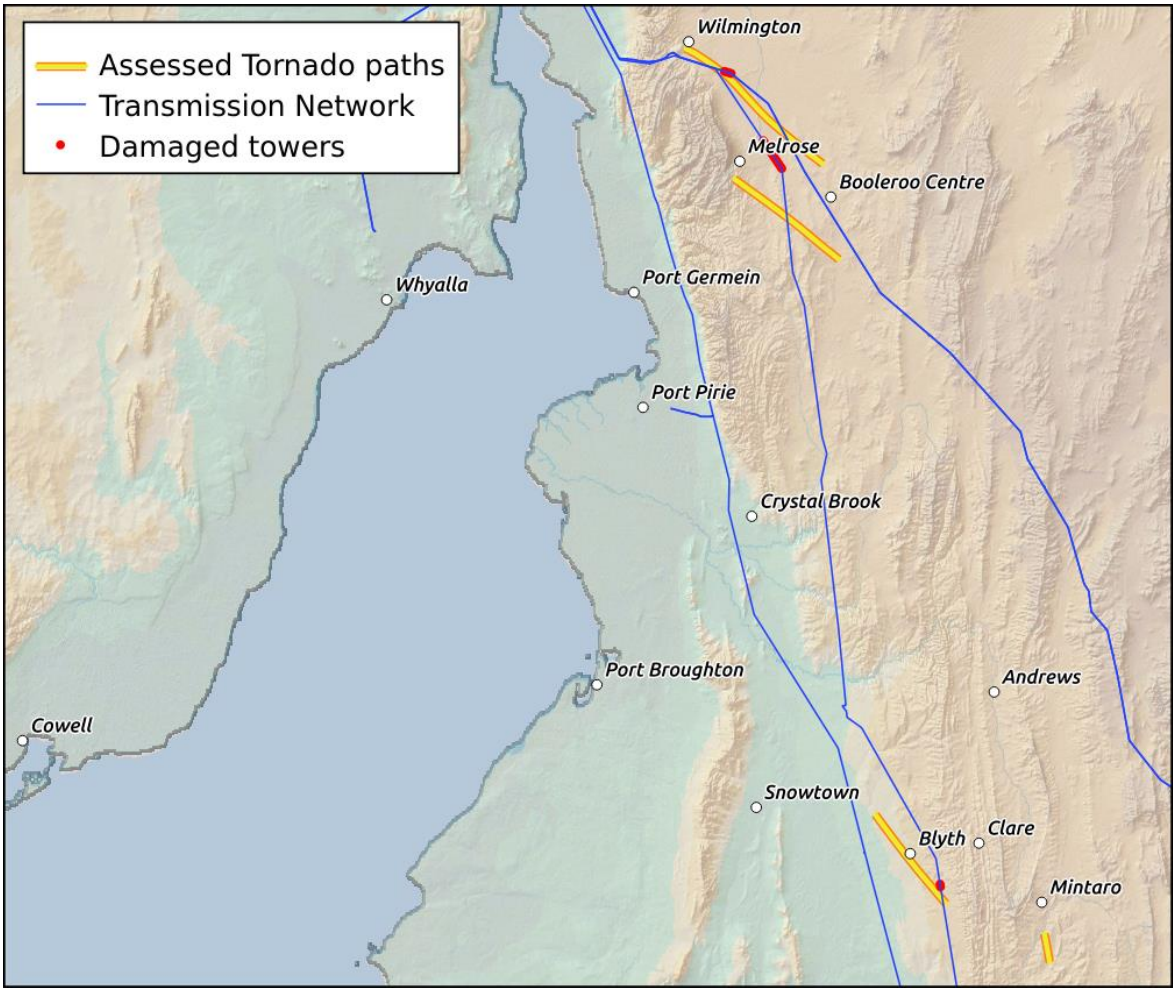

Figure 15: *The locations of the four assessed tornado paths overlaid with transmission network and damaged towers..*

A damage assessment was performed on 6 October across the Mid North and Flinders districts, with four of the seven identified areas of tornadic damage investigated (Figure 15). During the assessment, photographic evidence of the damage was captured and has been used to estimate the path and intensity of the tornadoes. All wind speed ranges given are estimates only (not measurements) based on the Enhanced Fujita (EF*)/Fujita (F) Scale of tornado damage. Damage was assigned an upper and lower bound of probable wind speeds using the damage indicators (DI) and degrees of damage (DOD) (McDonald & Mehta 2004)[2] given in the EF Scale. These were then converted to a rating in the F Scale (table 1), which is the standard tornado rating system used by the Bureau of Meteorology.

Without a thorough engineering analysis of tornado damage in any event, the actual wind speeds needed to cause that damage are unknown. It should also be noted that the EF Scale of tornado damage is based on human-built structures and vegetation in North America. Differences in construction standards and vegetation types increases the uncertainty of wind speed estimates given.

Fujita Scale	
Rating	**Estimated 3 Second Wind Gust Speed (km/h)**
F0	72 – 126
F1	127 – 189
F2	190 – 260
F3	261 – 337
F4	338 – 421
F5	422 – 510

Table 1: *Fujita Scale (converted from mph to km/h with rounding)*

Note the four rated tornadoes have been assessed in chronological order.

4.1 Blyth Tornado – Rated F2 Strength

Tornadic damage has been identified along an approximately 19 km long track, beginning northwest of Blyth in the Mid North and tracking to the southeast through farms, native vegetation, residential properties and community buildings in the township itself before ending to the south of Kybunga. Damage was not formally assessed to the southeast of Blyth; however damage to the Brinkworth – Templers West transmission, video footage and ground reports suggest it was ongoing south of Kybunga. The tower on the transmission line (Figure 24) has collapsed towards the northwest; this damage and the timing of the fault (see Impact on Power Transmission Network) are consistent with the path of the tornado (Figure 16). Based on radar evidence the tornado is estimated to have started at approximately 03:35 pm and finished at approximately 03:50 pm. This tornado has been rated at F2 strength, based on the damage indicators in table 2. The upper bound of wind speeds for damage marker 6 reach the low end of the F3 scale, but a lack of supportive evidence of this wind speed from other damage indicators excludes a rating beyond F2.

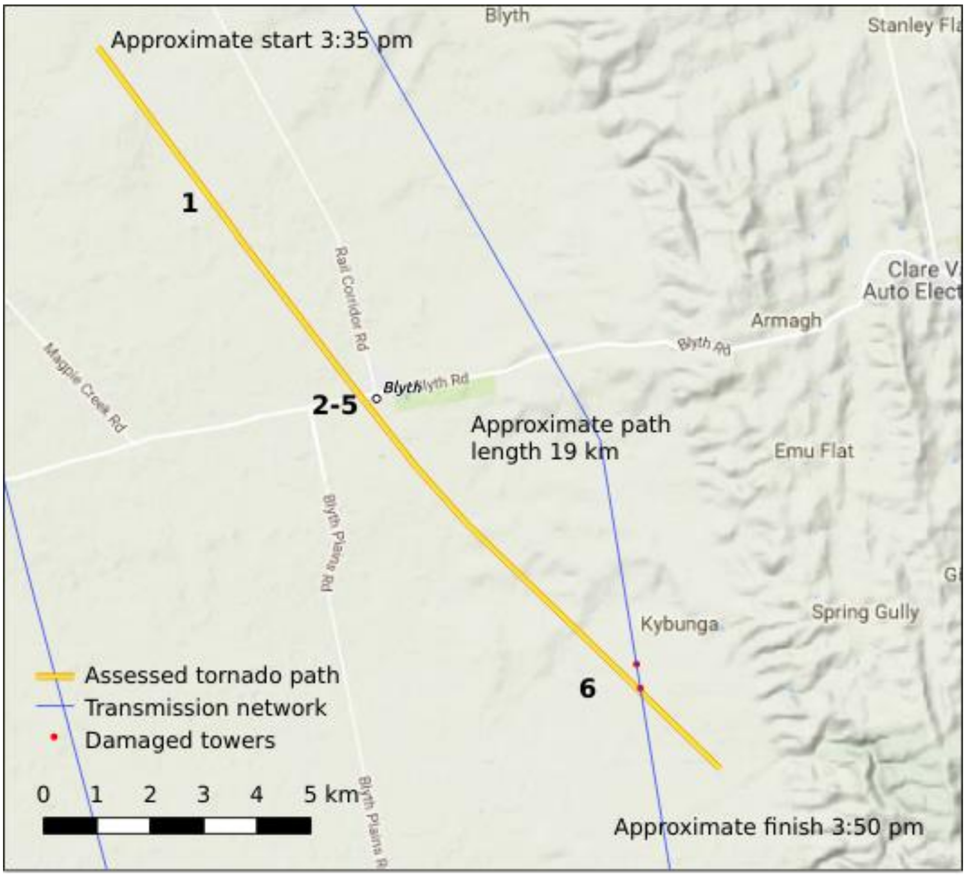

Figure 16: *Approximate Blyth tornado path with damage markers, transmission network (blue) and damaged towers (red).*

Damage Marker	Damage Description	Estimated Wind Speed (km/h)	Rating
1	A patch of native scrub (hardwood) showed large branches broken.	98 – 142	F0/F1
2	Church hall full loss of roof.	167 – 229	F1/F2
3	Large pine trees uprooted (softwood).	117 – 182	F0/F1
4	Loss of significant roof covering material (>20%) to multiple houses.	130 – 187	F1
5	Light object missile generated (wood beam thrown 200+ metres, piercing metal shed wall)	190 – 259	F2
6	Collapsed metal truss transmission line towers.	187 – 266	F2/F3

Table 2: *Blyth tornado description of damage, estimated wind speeds and corresponding rating*

Figure 17: *Blyth tornado damage marker 1.*

Figure 18: *Blyth tornado damage marker 2.*

Figure 19: *Blyth tornado damage marker 3.*

Figure 20: *Blyth tornado damage marker 4.*

Figure 21: *Blyth tornado damage marker 4.*

Figure 22: *Blyth tornado damage marker 5.*

Figure 23: *Blyth tornado damage marker 5.*

Figure 24: *Blyth tornado damage marker 6.*

Figure 25: *Still frame from video footage of the Blyth tornado. Credit Michael Jaeschke.*

Figure 26: *Still frame from video footage of the Blyth tornado. Credit Jace Bourne.*

Figure 27: *Still frame from video footage of the Blyth tornado crossing Blyth between 3:40 pm and 3:45 pm. Credit Michael Mathew.*

4.2 Wild Dog Creek Tornado – Rated F2 Strength

Tornadic damage has been identified along an approximately 23 km long track, beginning near Survey Road south of Melrose in the Flinders district. The tornado tracked to the southeast across the Horrocks Highway near Wild Dog Creek, continuing through farms and native vegetation before ending near the Appila road approximately 10 km south of Booleroo Centre. The precise start and end locations were not identified via the damage survey on 6 October, but have been estimated with a moderate level of confidence based on video footage, anecdotal evidence from local residents and radar information. Based on radar evidence the tornado is estimated to have started at approximately 03:35 pm and finished at 04:00 pm. This tornado has been rated at F2 strength, based on the damage indicators in table 3.

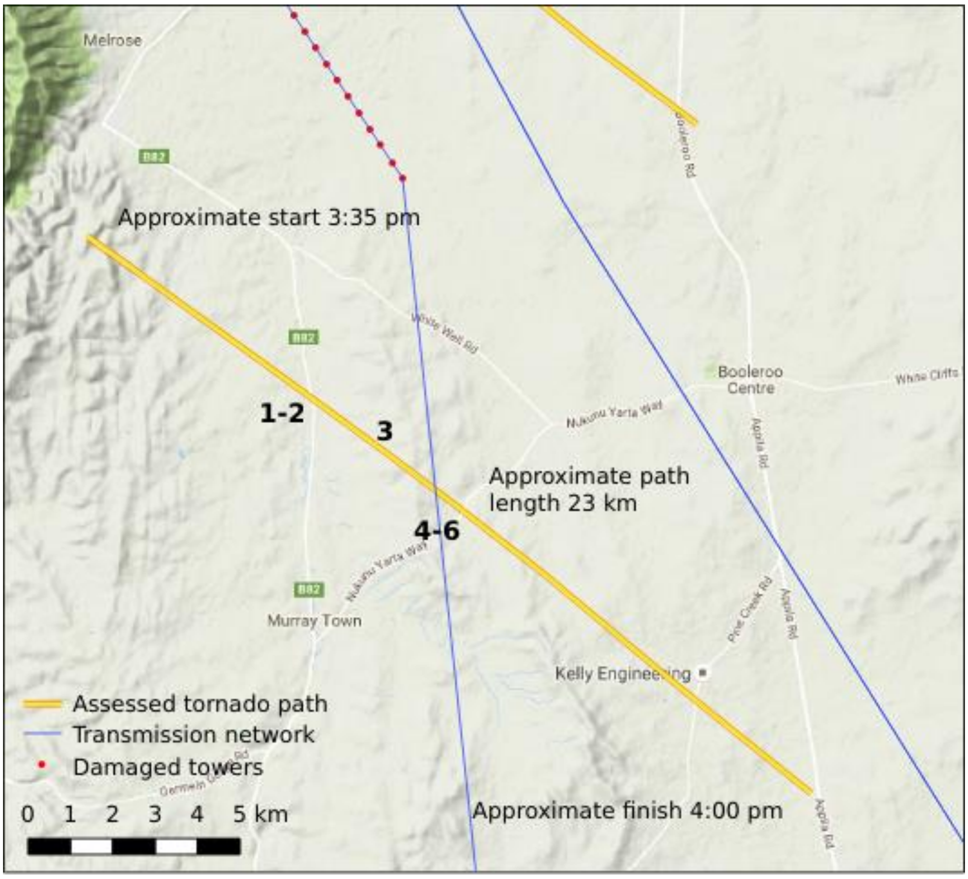

Figure 28: *Approximate Wild Dog Creek tornado path with damage markers, transmission network (blue) and damaged towers (red).*

Damage Marker	Damage Description	Estimated Wind Speed (km/h)	Rating
1-2	A patch of native scrub (hardwood) showed large branches broken.	98 – 142	F0/F1
3	Damage to metal shed, buckling of roof purlins.	153 – 222	F1/F2
4	Large field bins (1 ton+) thrown approximately 300 metres, rolling a further 300+ metres.	190 – 259	F2

Table 3: *Wild Dog Creek tornado description of damage, estimated wind speeds and corresponding rating.*

Figure 29: Wild Dog Creek tornado damage marker 1

Figure 30: Wild Dog Creek tornado damage marker 1.

Figure 31: Wild Dog Creek tornado damage marker 2.

Figure 32: Wild Dog Creek tornado damage marker 2.

Figure 33 *Wild Dog Creek tornado damage marker 3.*

Figure 34 *Wild Dog Creek tornado damage marker 3.*

Figure 35: *Wild Dog Creek tornado damage marker 4.*

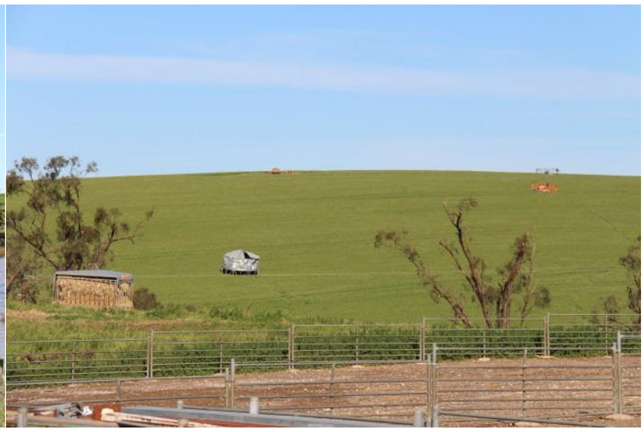

Figure 36: *Wild Dog Creek tornado damage marker 4.*

4.3 Wilmington Tornado – Rated F2 Strength

Tornadic damage was evident along an approximately 30 km long track, starting in southern parts of Wilmington and tracking to the southeast, through the Wilmington caravan park, across farms and native vegetation and ending approximately 6 km north of Booleroo near Booleroo road. The extent of damage further east of Booleroo is unknown, but a lessening of damage near the end of the analysed track is suggestive of the tornado weakening below tornadic strength. Based on radar

evidence the tornado is estimated to have started at approximately 03:45 pm and finished at 04:05 pm. This tornado has been rated at F2 strength, based on the damage indicators in table 4. The upper bound of wind speeds for damage markers 4, 5 and 6 reached the low end of the F3 scale, but a lack of supportive evidence of this wind speed from other damage indicators excludes a rating beyond F2. The wind speed estimates for this storm do however indicate that this was the strongest assessed tornado on the day and was likely at the upper end of F2. Damage to a section of trees along Spring Creek (Figure 48), nearby damage marker 4, gives a visual guide on the approximate width of the tornado at that point.

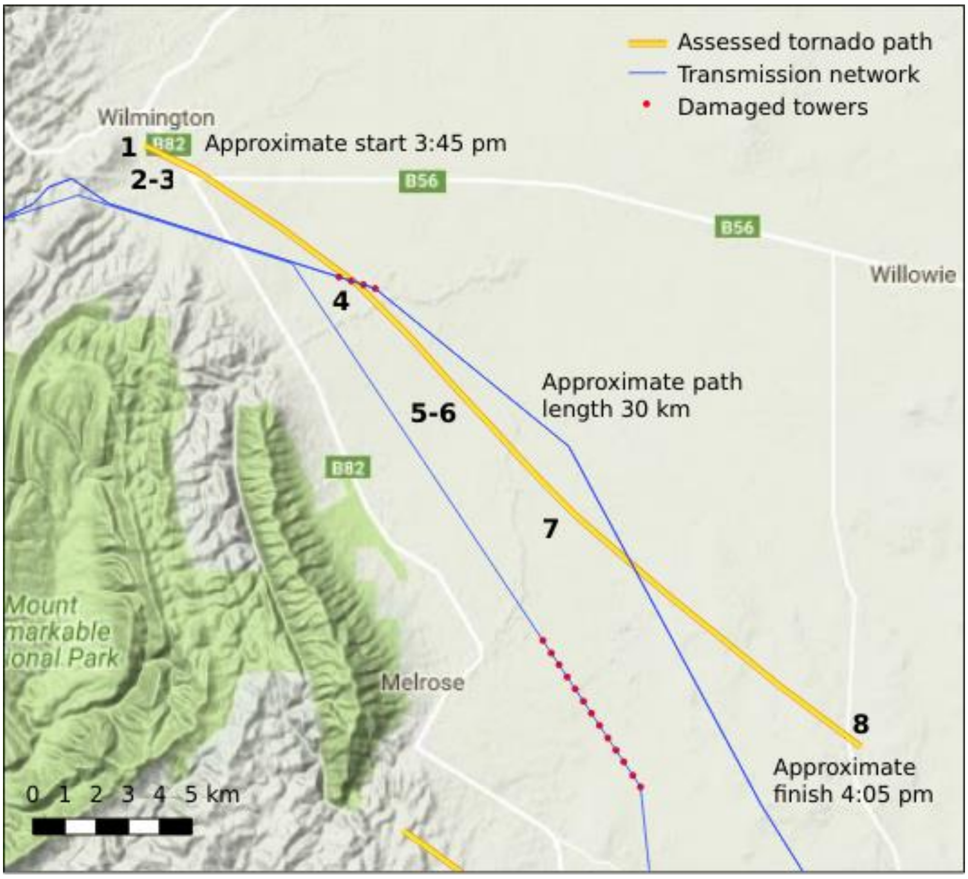

Figure 37: *Approximate Wilmington tornado path with damage markers, transmission network (blue) and damaged towers (red).*

Damage Marker	Damage Description	Estimated Wind Speed (km/h)	Rating
1	Large metal shed column anchorage failure.	154 – 217	F1/F2
2	A patch of native scrub (hardwood) showed large branches broken.	98 – 142	F0/F1
3	Caravan overturned.	127 – 188	F1
4	Collapsed metal truss transmission line towers.	187 – 266	F2/F3
5-6	Large gum trees (hardwood) with only stubs of largest branches remaining.	198 – 269	F2/F3
7	Total collapse of metal farm shed.	151 – 211	F1/F2
8	A patch of native scrub (hardwood) showed large branches broken.	98 – 142	F0/F1

Table 4: *Wilmington tornado description of damage, estimated wind speeds and corresponding rating.*

Figure 38: *Wilmington tornado damage marker 1.*

Figure 39: *Wilmington tornado damage marker 1.*

__Figure 40:__ Wilmington tornado damage marker 2.

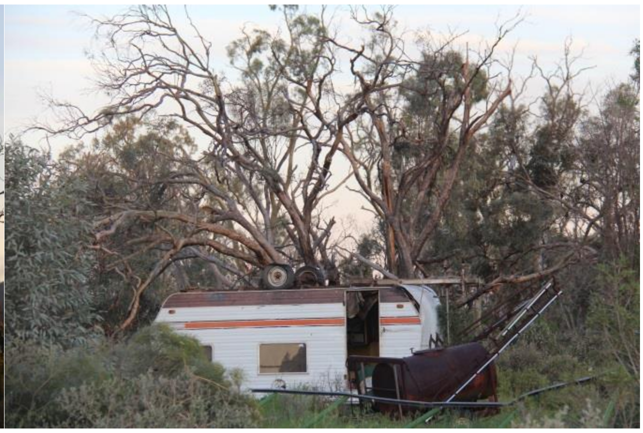

__Figure 41:__ Wilmington tornado damage marker 3.

__Figure 42:__ Wilmington tornado damage marker 4.

__Figure 43:__ Wilmington tornado damage marker 4.

Figure 44: *Wilmington tornado damage marker 5.*

Figure 45: *Wilmington tornado damage marker 6.*

Figure 46: *Wilmington tornado damage marker 7.*

Figure 47: *Wilmington tornado damage marker 8.*

Figure 48: *Tornadic damage to trees along Spring Creek, nearby damage marker 4, indicates the approximate width of the Wilmington tornado.*

Figure 49*: Still frame from video footage of Wilmington tornado. Credit Sharee and Locky McCallum.*

4.4 South Mintaro Tornado – Rated F1 Strength

Tornadic damage was evident along an approximately 4 km long track, starting approximately 5 km south of Mintaro in the Mid North and tracking to the south, through farms and native vegetation, before ending approximately near Brothers Hill road (Auburn-Manoora road). Based on radar evidence the tornado is estimated to have started at approximately 04:00 pm and finished at 04:05 pm. This tornado has been rated at F1 strength, based on the damage indicators in table 5. The upper bound of wind speeds for damage marker 3 reached the bottom threshold of the F2 scale, but the expected winds remain well within the F1 range.

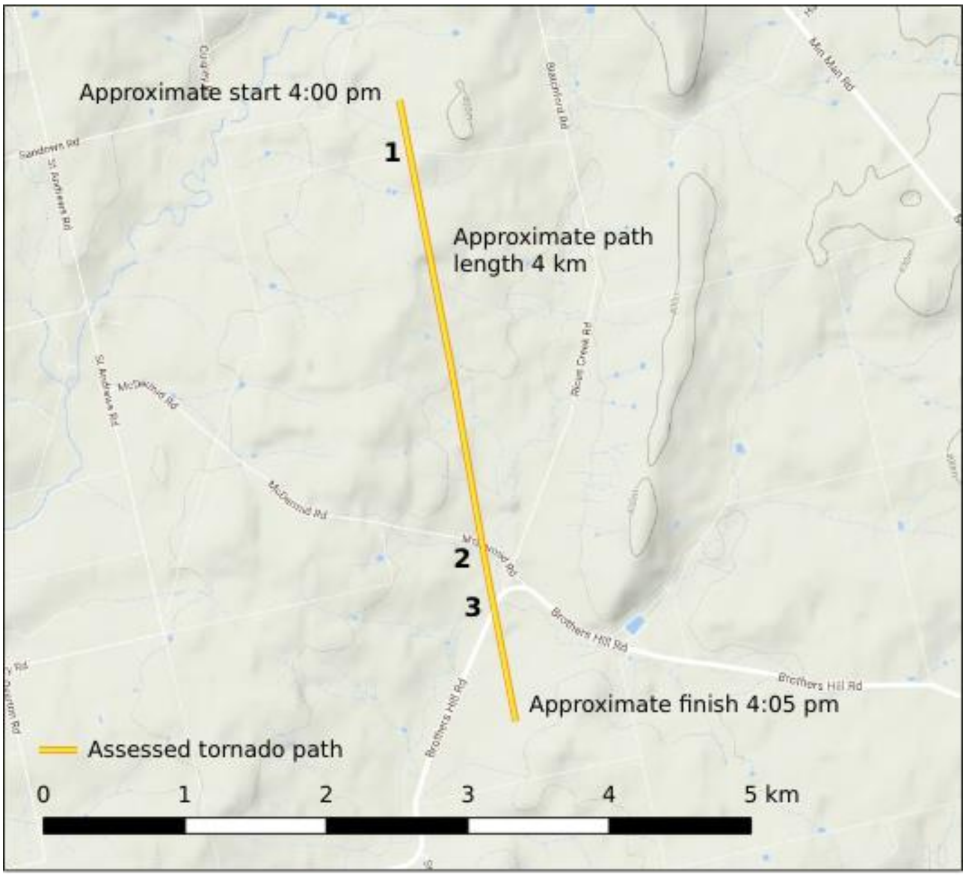

Figure 50: Approximate South Mintaro tornado path with damage markers.

Damage Marker	Damage Description	Estimated Wind Speed (km/h)	Rating
1	A patch of native scrub (hardwood) showed large branches broken.	98 – 142	F0/F1
2	A patch of native scrub (hardwood) showed large branches broken.	98 – 142	F0/F1
3	Uprooted gum trees (hardwood).	122 – 190	F0/F1/F2

Table 5: *South Mintaro tornado description of damage, estimated wind speeds and corresponding rating.*

Figure 51: *South Mintaro tornado damage marker 1.*

Figure 52: *South Mintaro tornado damage marker 1.*

Figure 53: *South Mintaro tornado damage marker 2.*

Figure 54: *South Mintaro tornado damage marker 3.*

5 Impact on Power Transmission Network

On Wednesday 28 September 2016, at 03:48 pm electricity supply was lost across the state of South Australia (Black System Event) (AEMO[1]) [3], [4]. The loss of supply corresponded with a widespread outbreak of supercell thunderstorms with an exceptional number of tornadoes. An analysis of meteorological data including satellite, radar, surface and upper air observations as well as on ground damage assessments has been performed, with the aim of determining the impact of the severe weather on the network.

Five faults led to the Black System Event, with four of these occurring on three transmission lines (Brinkworth - Templars West, Davenport - Belalie and Davenport - Mt Lock) (AEMO)[3], [4]. A damage assessment on 6 October has identified that these faults were caused by the impact of supercell thunderstorms and tornadoes. Along with the faults reported by AEMO, it is likely that severe weather also led to damage on the Davenport - Brinkworth transmission line, shortly after the state-wide blackout had occurred.

Brinkworth - Templars West Transmission Line

Refer damage assessment for tornado track map and assessment.

Radar evidence indicates a supercell thunderstorm in the vicinity of the two damaged transmission towers on the Brinkworth - Templars West transmission line between 03:40 pm and 03:50 pm. On the ground damage surveys and video evidence confirm the presence of the F2 Blyth tornado, with estimated peak wind gusts of 190 – 260 km/h. The timing and location of the tornado is consistent with the faults on this line at 03:47:33 pm CST (AEMO) [3], [4].

Davenport – Belalie/Davenport - Mt Lock Transmission Lines

Refer damage assessment for tornado track map and assessment.

The Davenport – Belalie/Davenport - Mt Lock transmission lines are both on the same double circuit towers (AEMO) [3], [4]. Radar evidence indicates a supercell thunderstorm in the vicinity of the five damaged transmission towers between 03:45 pm and 03:55 pm. On the ground damage surveys as well as video evidence confirm the presence of the F2 Wilmington tornado, with estimated peak wind gusts of 190 – 260 km/h. The five damaged power transmission poles were in the direct path of the surveyed tornado track (see Figure 56). The timing and location of the tornado is consistent with the faults on these lines between 03:47:59 pm CST and 03:48:14 pm CST (AEMO) [3], [4].

[1] AEMO reports state times in AEST, half an hour ahead of CST.

Davenport - Brinkworth Transmission Line

The Davenport - Brinkworth transmission line was also impacted by the supercell thunderstorm that produced the Wilmington tornado and damaged the Davenport - Belalie and Davenport - Mt Lock transmission lines. The preliminary AEMO report [3] suggests this damage occurred after the state-wide blackout. A total of 14 towers were damaged and these were located well to the south of the Wilmington tornado damage path. In the vicinity of the towers there was little evidence of significant damage to vegetation or structures, indicating that these towers were not directly impacted by a tornado. Figure 55 shows the damaged towers on the transmission line and was taken on Girdham Rd looking northwest with towers collapsed towards the northeast.

Figure 55: *Damaged towers on the Davenport – Brinkworth transmission line*

Radar evidence suggests that supercell thunderstorms were oriented with the tornado and rear flank downdraft to the north/northwest and the forward flank downdraft to the south/southeast. Based on the position and collapse orientation of the damaged towers compared to the radar and tornado track, it is theorised that the 14 towers were impacted by the forward flank downdraft, a broad region of mostly straight-line thunderstorm outflow (see Figure 56). The timing of this impact is likely to have been within minutes after the state-wide black out.

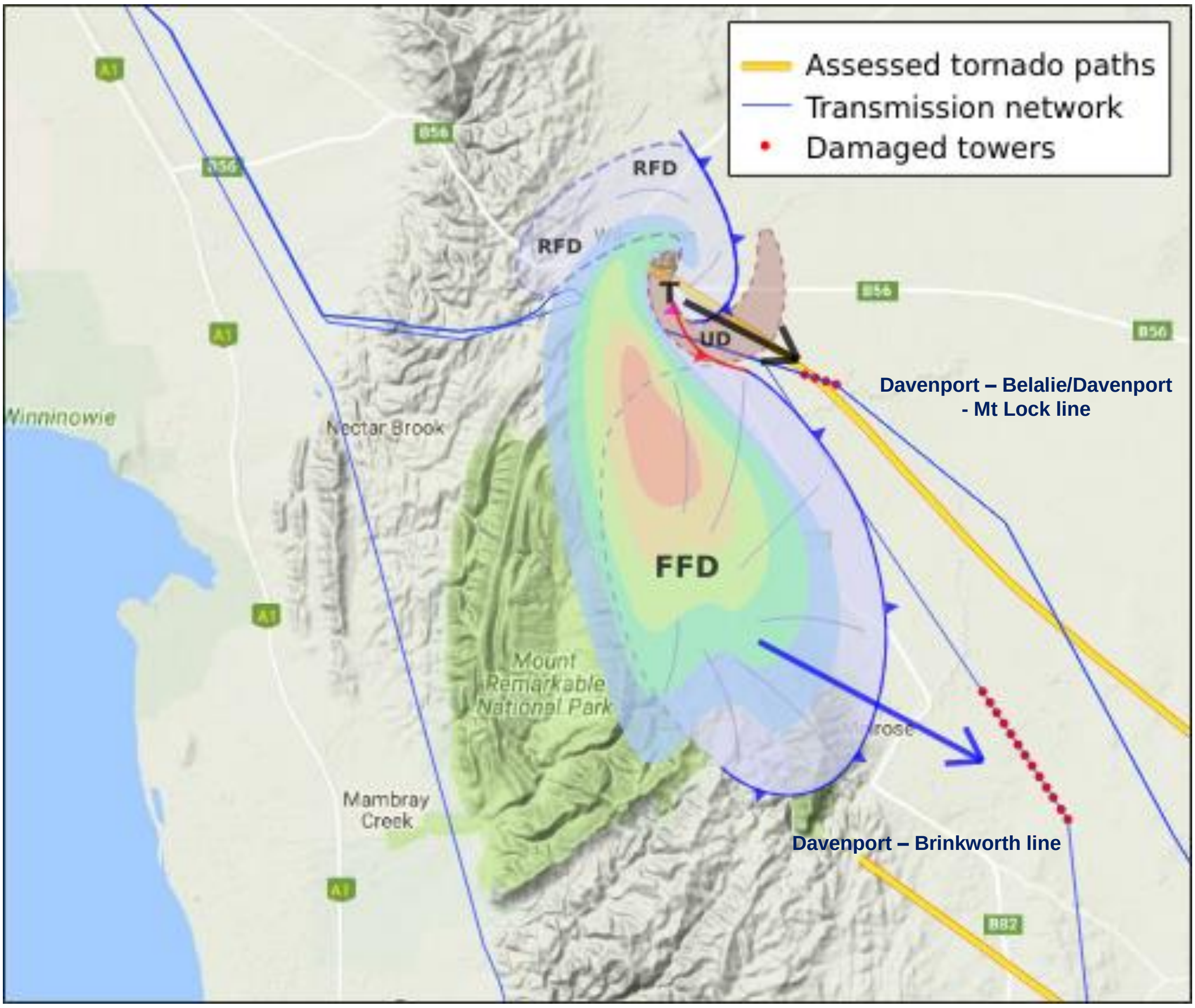

Figure 56: Idealised Wilmington supercell thunderstorm, depicting the position of the tornado(T), forward flank downdraft (FFD) and how they impacted the Davenport – Belalie/Davenport - Mt Lock and Davenport - Brinkworth Transmission Lines respectively. Also shown is the rear flank downdraft (RFD) and updraft region (UD).

Port Lincoln – Yadnarie Transmission Line

The preliminary AEMO [3] report indicates a single tower was damaged on the Port Lincoln - Yadnarie transmission line, likely after the state-wide blackout. Unfortunately a damage assessment could not be performed in this region. Without the timing of this failure and a damage

assessment it is difficult to suggest a direct weather related cause. It is possible however to suppose that the period of damaging to destructive broad scale winds over much of Eyre Peninsula due to the deep low pressure system to the south early on 29 September, may have contributed to the damage that occurred.

6 Warnings Timeline

In the days prior to the 28 September varying sources of numerical weather prediction (NWP) guidance were analysed and the potential for a significant thunderstorm outbreak was recognised. Continually updated advice was conveyed to emergency services via the regular verbal briefings and outlook products provided to emergency services by the contracted embedded meteorologist. The publicly available warning service (Table 6) provided by the Bureau of Meteorology aims to give detailed short lead time and frequently updated warnings of severe thunderstorms.

All severe thunderstorm warnings issued by the Bureau of Meteorology on 28 September have been included in Figures 53 – 59 in Appendix B. A summary of warnings is available in Table 6.

The first official severe thunderstorm warning was issued at 10:10 am for damaging wind gusts over western districts. An upgraded warning was issued at 12:26 pm for destructive wind gusts, large hail and heavy rainfall over western and central districts. As the thunderstorms tracked to the south and east further updates to warnings were issued for the same phenomena at 02:10 pm, 03:23 pm and 05:22 pm. Thunderstorm warnings were then downgraded to damaging wind gusts only as the system tracked east, these were issued at 06:42 pm and 07:46 pm. The severe thunderstorm warning was cancelled at 10:56 pm.

Time (CST)	Severe Phenomena	Districts Warned
10:10 am	Damaging wind.	Lower Eyre Peninsula, Eastern Eyre Peninsula and parts of the West Coast and North West Pastoral.
12:26 pm	Destructive wind, Heavy rainfall and Large Hailstones.	Eastern Eyre Peninsula, Flinders and parts of the Yorke Peninsula, Mid North, North West Pastoral and North East Pastoral.
02:10 pm	Destructive wind, Heavy rainfall and Large Hailstones.	Eastern Eyre Peninsula, Yorke Peninsula, Flinders and parts of the Mid North, North West Pastoral and North East Pastoral.
03:23 pm	Destructive wind, Heavy rainfall and Large Hailstones.	Adelaide Metropolitan, Mount Lofty Ranges, Yorke Peninsula, Flinders, Mid North and parts of the Eastern Eyre Peninsula, Murraylands, North West Pastoral and North East Pastoral.
05:22 pm	Destructive wind, Heavy rainfall and Large Hailstones.	Flinders, Riverland and parts of the Mid North and North East Pastoral.
06:42 pm	Damaging wind.	Parts of the Riverland and North East Pastoral.
07:46 pm	Damaging wind.	Parts of the Riverland and North East Pastoral.
10:56 pm	Cancelled.	Nil.

Table 6: *Summary of Severe Thunderstorm Warnings issued.*

7 Summary

A severe thunderstorm and tornado outbreak impacted central and eastern districts of South Australia on 28 September 2016. Multiple supercell thunderstorms produced damaging to destructive winds, very large hailstones, locally intense rainfall and at least seven tornadoes.

Diagnosis of the initiation and evolution of supercell thunderstorms was achieved utilising numerical model guidance, radar, weather satellite and weather station data.

Damage inspection by skilled meteorologists has been used to deduct track length and strength of four tornadoes. Anecdotal damage reports are consistent with at least three additional tornadoes. Overlaying the different data types and integrating the meteorological data with maps of power network infrastructure assisted analysis.

On this occasion critical infrastructure was damaged by an extreme weather event. This report has described the environment and accompanying phenomena, utilising the best available technologies and expertise within the Bureau of Meteorology.
Additional data may have provided even more beneficial insights. Collaborative investigations with partner agencies would be encouraged by the Bureau of Meteorology. Additional information could be sourced from joined-up infrastructure inspections and additional remote sensing, such as high resolution satellite tasking or aerial reconnaissance. There are also opportunities for sharing of private automated weather station network data.

The climatological return period for destructive severe thunderstorms has not been considered in this report. Sophisticated climatological studies into the frequency of high impact are now possible utilising reanalysis data. The Bureau has recently commenced generating highly accurate numerical model simulations of the atmosphere for the last 25 years. At hourly (or better) time steps the 1.5 km grid resolution will enable users to resolve regional patterns, with an understanding of local topography, coastal influences and shifts over time driven by climate change. Studies can consider the risk profiles for different categories of fire weather, drought, wind characteristics, flood and severe thunderstorms, amongst a wide range of phenomena.

8 References

1. Smith, B et al (2015). Diagnosing the Conditional Probability of Tornado Damage Rating Using Environmental and Radar Attributes. NOAA/NWS/NCEP/Storm Prediction Center, Norman, Oklahoma.
2. McDonald, J; Mehta K, (2004). A recommendation for an Enhanced Fujita scale (EF-Scale). Lubbock, Texas: Wind Science and Engineering Research Center*,* Texas Tech University.
3. Australian Energy Market Operator Ltd., (2016). Preliminary Report – Black System Event in South Australia on 28 September 2016. [Online] Available at: https://www.aemo.com.au/Media-Centre.
4. Australian Energy Market Operator Ltd., (2016). Updated Report – Black System Event in South Australia on 28 September 2016. [Online] Available at: https://www.aemo.com.au/Media-Centre.

9 Appendices

Appendix A – Supporting Radar Evidence

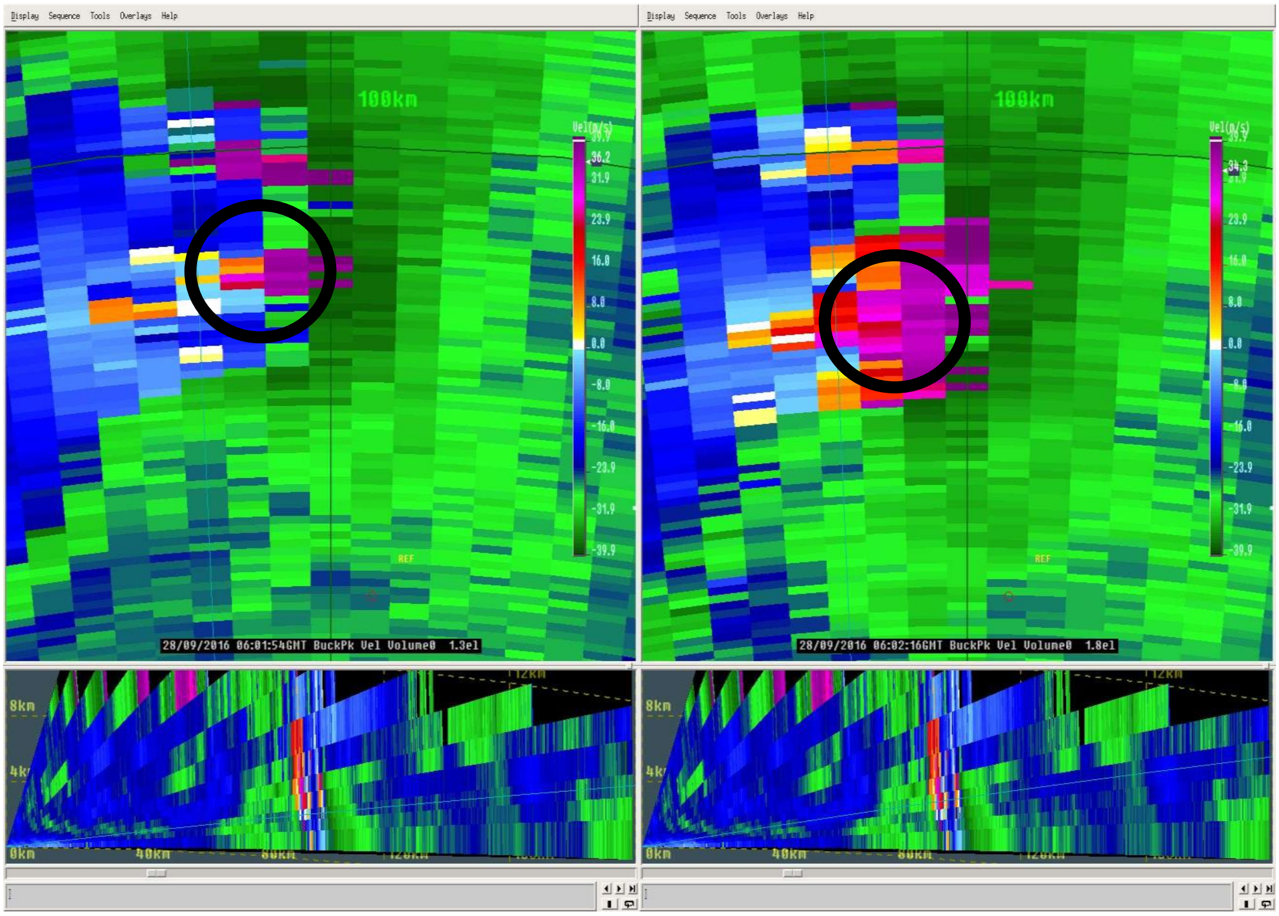

Figure 57: *Buckland Doppler Radar 1.3° (left) and 1.8° (right) velocity scans at 03:32 pm of the supercell thunderstorm responsible for the Blyth tornado. Peak rotational velocities are 27.2 m/s and 28.2 m/s respectively (circled in black).*

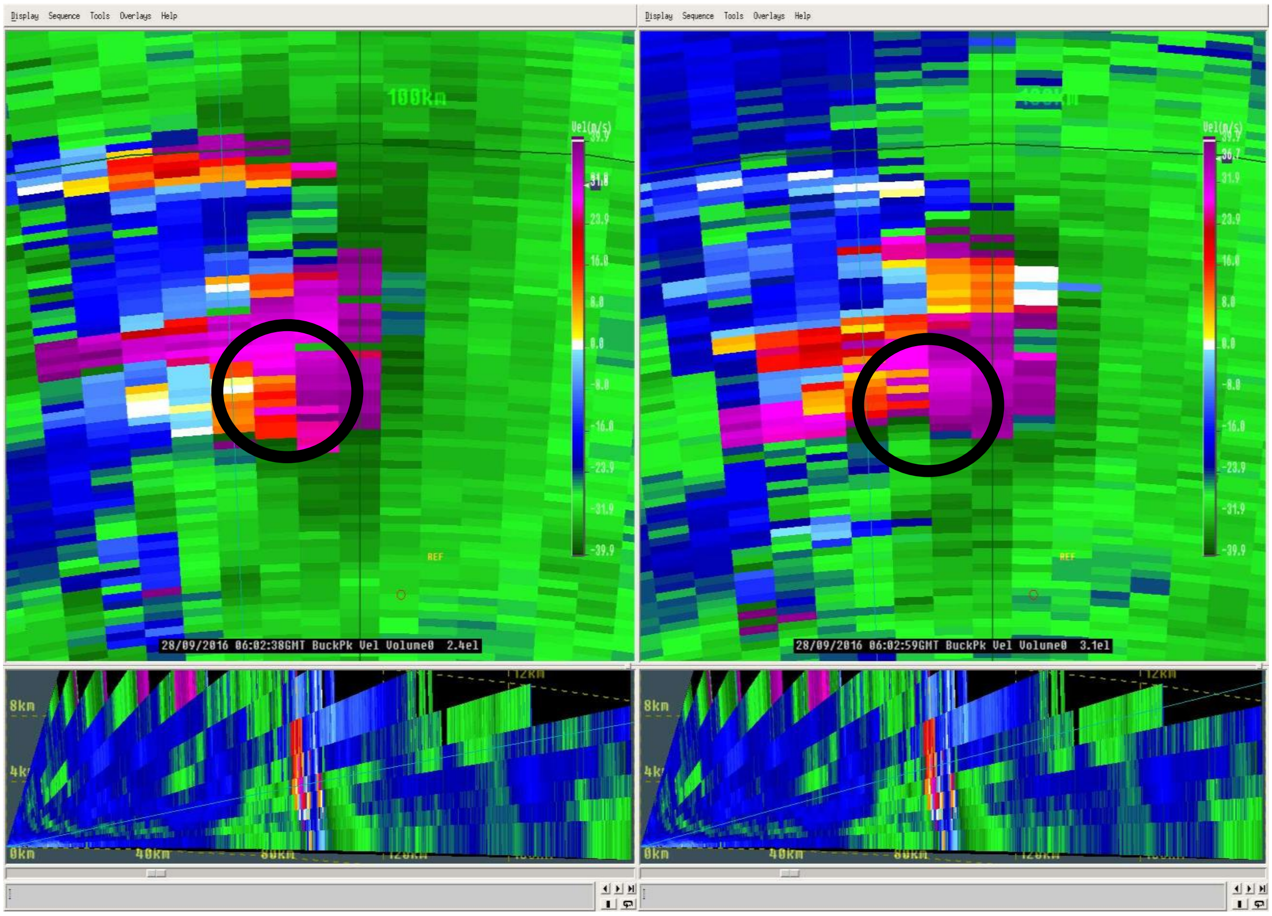

Figure 58: *Buckland Doppler Radar 2.4° (left) and 3.1° (right) velocity scans at 03:33 pm of the supercell thunderstorm responsible for the Blyth tornado. Peak rotational velocities are 30.7 m/s and 26.7 m/s respectively (circled in black).*

Appendix B – Warnings

IDS65502
Australian Government Bureau of Meteorology
South Australia Regional Office

TOP PRIORITY FOR IMMEDIATE BROADCAST

SEVERE THUNDERSTORM WARNING

for DAMAGING WIND

For people in the
Lower Eyre Peninsula,
Eastern Eyre Peninsula and parts of the
West Coast and
North West Pastoral districts.

Issued at 10:10 am Wednesday, 28 September 2016.

Severe thunderstorms are likely to produce damaging wind gusts in excess of 90 km/h in the warning area over the next several hours. Locations which may be affected include Port Lincoln, Whyalla, Roxby Downs, Elliston, Cleve and Woomera.

The State Emergency Service advises that people should:
* Secure or put away loose items around your property.
* Move cars under cover or away from trees.
* Keep clear of fallen power lines.
* Stay indoors, away from windows, while storms are nearby.

The next warning is due to be issued by 1:10 pm.

Warnings are also available through TV and Radio broadcasts, the Bureau's website at www.bom.gov.au or call 1300 659 215. The Bureau and State Emergency Service would appreciate warnings being broadcast regularly.

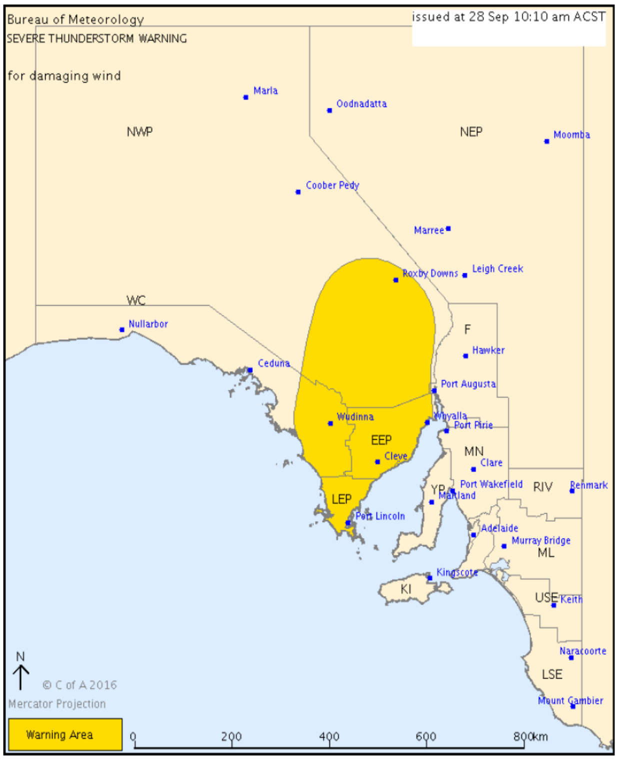

Figure 59: Severe Thunderstorm Warning issued at 10:10 am

IDS65502
Australian Government Bureau of Meteorology
South Australia Regional Office

TOP PRIORITY FOR IMMEDIATE BROADCAST

SEVERE THUNDERSTORM WARNING

for DESTRUCTIVE WIND, HEAVY RAINFALL and LARGE HAILSTONES

For people in the Eastern Eyre Peninsula, Flinders and parts of the Yorke Peninsula, Mid North, North West Pastoral and North East Pastoral districts.

Issued at 12:26 pm Wednesday, 28 September 2016.

Severe thunderstorms are likely to produce destructive wind gusts up to 140 km/h, heavy rainfall that may lead to flash flooding and large hailstones in the warning area over the next several hours. Locations which may be affected include Whyalla, Port Augusta, Hawker, Port Pirie, Clare, Roxby Downs and Leigh Creek.

Severe thunderstorms are no longer occurring in the West Coast and Lower Eyre Peninsula districts and the warning for these districts is CANCELLED.

The State Emergency Service advises that people should:
* Secure or put away loose items around your property.
* Move cars under cover or away from trees.
* Keep clear of fallen power lines.
* Don't drive, ride or walk through flood water.
* Keep clear of creeks and storm drains.
* Stay indoors, away from windows, while storms are nearby.

The next warning is due to be issued by 3:30 pm.

Warnings are also available through TV and Radio broadcasts, the Bureau's website at www.bom.gov.au or call 1300 659 215. The Bureau and State Emergency Service would appreciate warnings being broadcast regularly.

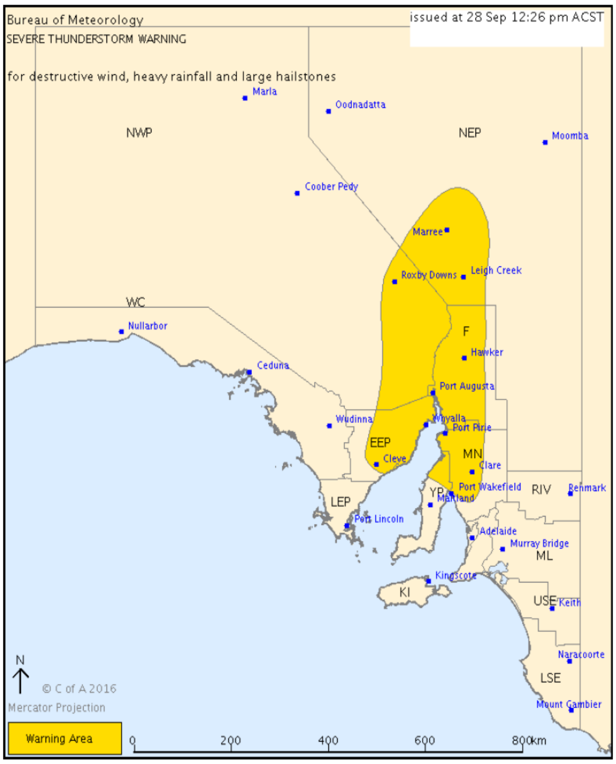

Figure 60: *Severe Thunderstorm Warning issued at 12:26 pm*

IDS65502
Australian Government Bureau of Meteorology
South Australia Regional Office

TOP PRIORITY FOR IMMEDIATE BROADCAST

SEVERE THUNDERSTORM WARNING

for DESTRUCTIVE WIND, HEAVY RAINFALL and LARGE HAILSTONES

For people in the Eastern Eyre Peninsula, Yorke Peninsula, Flinders and parts of the Mid North, North West Pastoral and North East Pastoral districts.

Issued at 2:10 pm Wednesday, 28 September 2016.

Severe thunderstorms are likely to produce destructive wind gusts to 140 km/h, heavy rainfall that may lead to flash flooding and large hailstones in the warning area over the next several hours. Locations which may be affected include Whyalla, Port Pirie, Clare, Maitland, Roxby Downs and Leigh Creek.

A thunderstorm produced large hailstones at Cleve, a gust to 87 km/h and 14 mm in 15 minutes earlier this afternoon.

The State Emergency Service advises that people should:
* Secure or put away loose items around your property.
* Move cars under cover or away from trees.
* Keep clear of fallen power lines.
* Don't drive, ride or walk through flood water.
* Keep clear of creeks and storm drains.
* Stay indoors, away from windows, while storms are nearby.

The next warning is due to be issued by 5:10 pm.

Warnings are also available through TV and Radio broadcasts, the Bureau's website at www.bom.gov.au or call 1300 659 215. The Bureau and State Emergency Service would appreciate warnings being broadcast regularly.

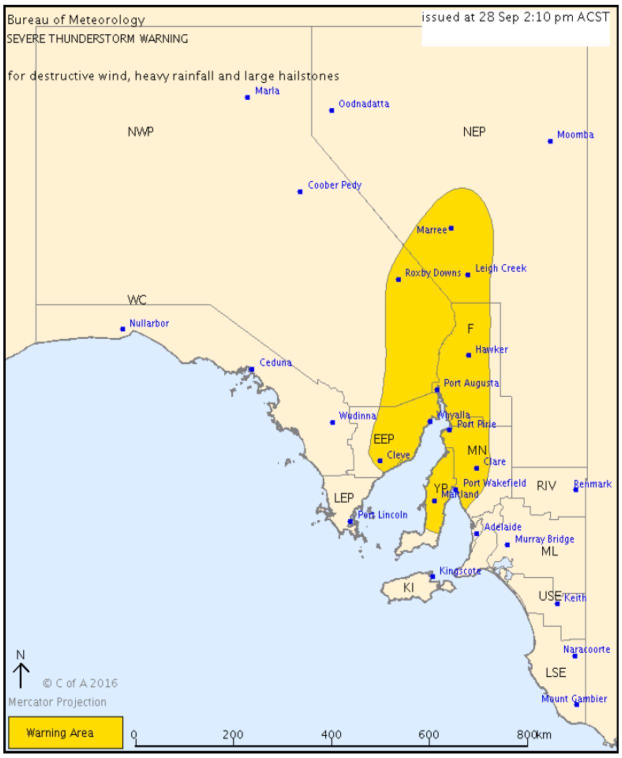

__Figure 61:__ Severe Thunderstorm Warning issued at 02:10 pm

IDS65502
Australian Government Bureau of Meteorology
South Australia Regional Office

TOP PRIORITY FOR IMMEDIATE BROADCAST

SEVERE THUNDERSTORM WARNING

for DESTRUCTIVE WIND, HEAVY RAINFALL and LARGE HAILSTONES

For people in the Adelaide Metropolitan, Mount Lofty Ranges, Yorke Peninsula, Flinders, Mid North and parts of the Eastern Eyre Peninsula, Murraylands, North West Pastoral and North East Pastoral districts.

Issued at 3:23 pm Wednesday, 28 September 2016.

Severe thunderstorms are likely to produce destructive wind gusts to 140 km/h, heavy rainfall that may lead to flash flooding and large hailstones in the warning area over the next several hours. Locations which may be affected include Whyalla, Clare, Maitland, Hawker and Leigh Creek.

Severe thunderstorms with heavy rainfall that may lead to flash flooding and damaging wind gusts of 90-100 km/h are expected in the Adelaide Metropolitan and Mount Lofty Ranges districts. Large hailstones are not expected in these districts.

A thunderstorm produced large hailstones at Cleve, a gust to 87 km/h and 14 mm in 15 minutes earlier this afternoon.

The State Emergency Service advises that people should:
* Secure or put away loose items around your property.
* Move cars under cover or away from trees.
* Keep clear of fallen power lines.
* Don't drive, ride or walk through flood water.
* Keep clear of creeks and storm drains.
* Stay indoors, away from windows, while storms are nearby.

The next warning is due to be issued by 6:25 pm.

If severe thunderstorms develop in the Adelaide Region, a more detailed Severe Thunderstorm Warning will be issued to people in this area.

Warnings are also available through TV and Radio broadcasts, the Bureau's website at www.bom.gov.au or call 1300 659 215. The Bureau and State Emergency Service would appreciate warnings being broadcast regularly.

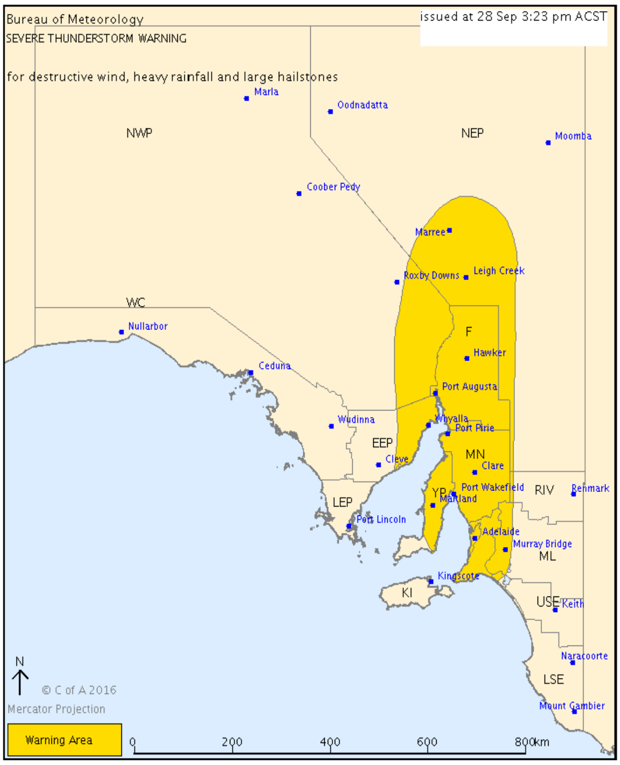

__Figure 62:__ Severe Thunderstorm Warning issued at 03:23 pm

IDS65502
Australian Government Bureau of Meteorology
South Australia Regional Office

TOP PRIORITY FOR IMMEDIATE BROADCAST

SEVERE THUNDERSTORM WARNING

for DESTRUCTIVE WIND, HEAVY RAINFALL and LARGE HAILSTONES

For people in the
Flinders,
Riverland and parts of the
Mid North and
North East Pastoral districts.

Issued at 5:22 pm Wednesday, 28 September 2016.

Severe thunderstorms are likely to produce destructive wind gusts to 140 km/h, heavy rainfall that may lead to flash flooding and large hailstones in the warning area over the next several hours. Locations which may be affected include Leigh Creek, Hawker, Waikerie, Arkaroola, Peterborough and Olary.

Severe thunderstorms are no longer occurring in the Adelaide Metropolitan, Mount Lofty Ranges, Eastern Eyre Peninsula, Yorke Peninsula, Murraylands and North West Pastoral districts and the warning for these districts is CANCELLED.

A thunderstorm produced large hailstones at Cleve, a gust to 87 km/h and 14 mm in 15 minutes earlier this afternoon.
Snowtown recorded a wind gust to 104 km/h and Clare recorded 26 mm in 1 hour this afternoon.

The State Emergency Service advises that people should:
* Secure or put away loose items around your property.
* Move cars under cover or away from trees.
* Keep clear of fallen power lines.
* Don't drive, ride or walk through flood water.
* Keep clear of creeks and storm drains.
* Stay indoors, away from windows, while storms are nearby.

The next warning is due to be issued by 8:25 pm.

Warnings are also available through TV and Radio broadcasts, the Bureau's website at www.bom.gov.au or call 1300 659 215. The Bureau and State Emergency Service would appreciate warnings being broadcast regularly.

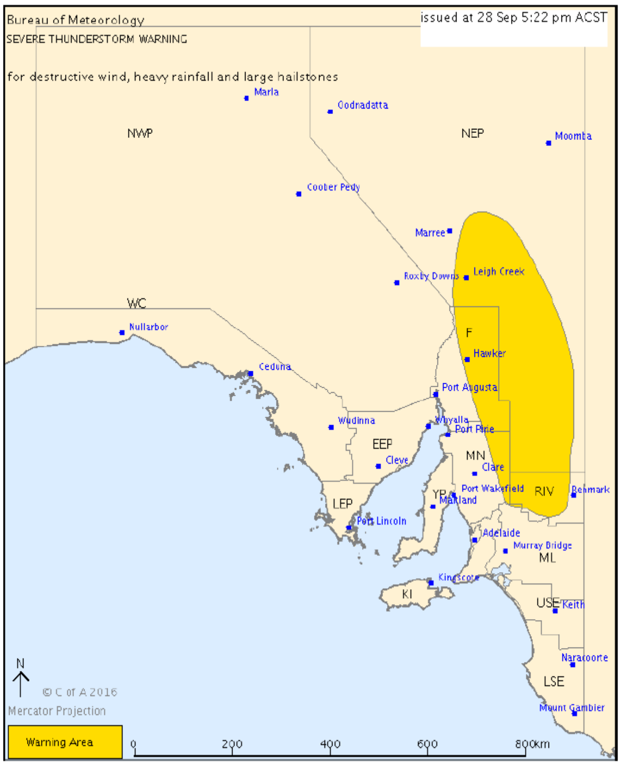

Figure 63: *Severe Thunderstorm warning issued at 05:22 pm*

IDS65502
Australian Government Bureau of Meteorology
South Australia Regional Office

TOP PRIORITY FOR IMMEDIATE BROADCAST

SEVERE THUNDERSTORM WARNING

for DAMAGING WIND

For people in parts of the
Riverland and
North East Pastoral districts.

Issued at 6:42 pm Wednesday, 28 September 2016.

Severe thunderstorms are likely to produce damaging wind gusts in excess of 90 km/h in the warning area over the next several hours. Locations which may be affected include Renmark, Arkaroola, Olary and Danggali Conservation Park.

Severe thunderstorms are no longer occurring in the Flinders and Mid North districts and the warning for these districts is CANCELLED.

Snowtown recorded a wind gust to 104 km/h in a thunderstorm this afternoon and Clare recorded 26mm in 1 hour this afternoon.

The State Emergency Service advises that people should:
* Secure or put away loose items around your property.
* Move cars under cover or away from trees.
* Keep clear of fallen power lines.
* Stay indoors, away from windows, while storms are nearby.

The next warning is due to be issued by 9:45 pm.

Warnings are also available through TV and Radio broadcasts, the Bureau's website at www.bom.gov.au or call 1300 659 215. The Bureau and State Emergency Service would appreciate warnings being broadcast regularly.

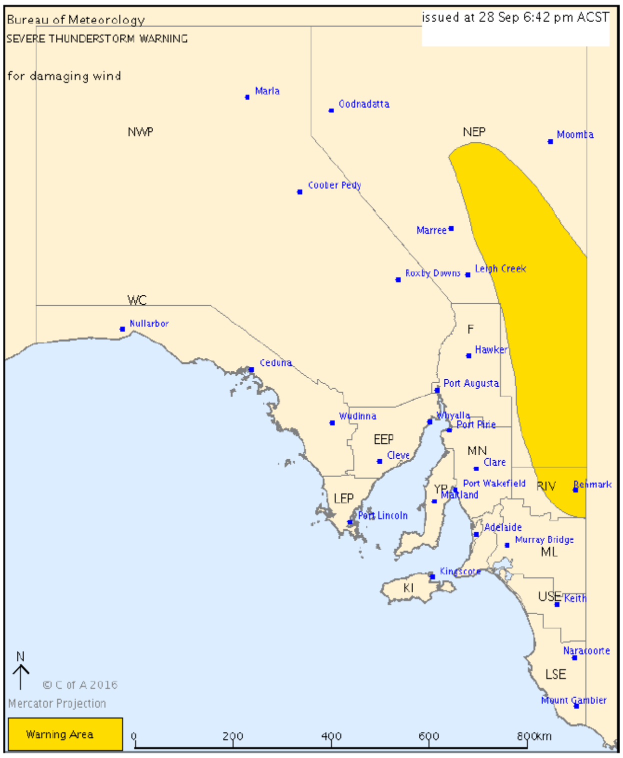

Figure 64: *Severe Thunderstorm warning issued at 06:42 pm*

IDS65502

Australian Government Bureau of Meteorology
South Australia Regional Office

TOP PRIORITY FOR IMMEDIATE BROADCAST

SEVERE THUNDERSTORM WARNING

for DAMAGING WIND

For people in parts of the
Riverland and
North East Pastoral districts.

Issued at 7:46 pm Wednesday, 28 September 2016.

Severe thunderstorms are likely to produce damaging wind gusts in excess of 90 km/h in the warning area over the next several hours. Locations which may be affected include Renmark, Moomba, Arkaroola and Olary.

Snowtown recorded a wind gust to 104 km/h in a thunderstorm this afternoon and Clare recorded 26mm in 1 hour this afternoon.

The State Emergency Service advises that people should:
* Secure or put away loose items around your property.
* Move cars under cover or away from trees.
* Keep clear of fallen power lines.
* Stay indoors, away from windows, while storms are nearby.

The next warning is due to be issued by 10:50 pm.

Warnings are also available through TV and Radio broadcasts, the Bureau's website at www.bom.gov.au or call 1300 659 215. The Bureau and State Emergency Service would appreciate warnings being broadcast regularly.

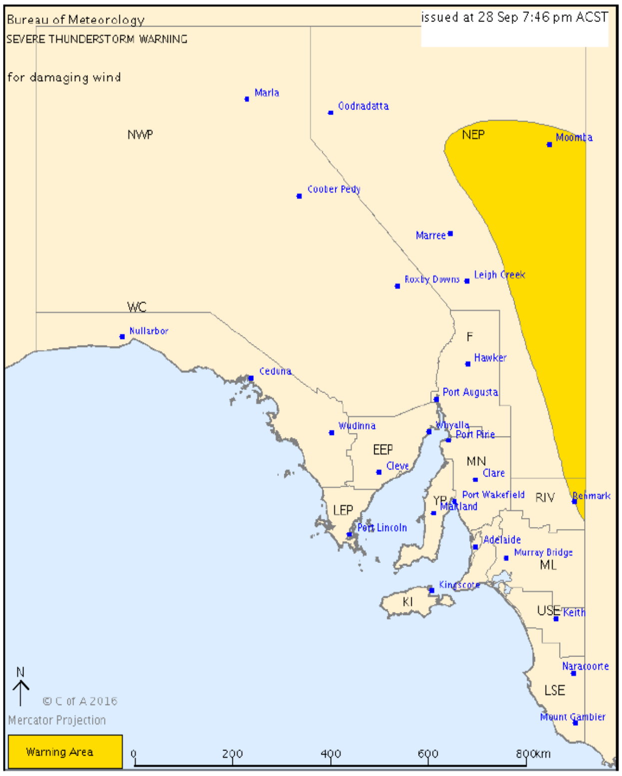

Figure 65: *Severe Thunderstorm warning issued at 07:46 pm*