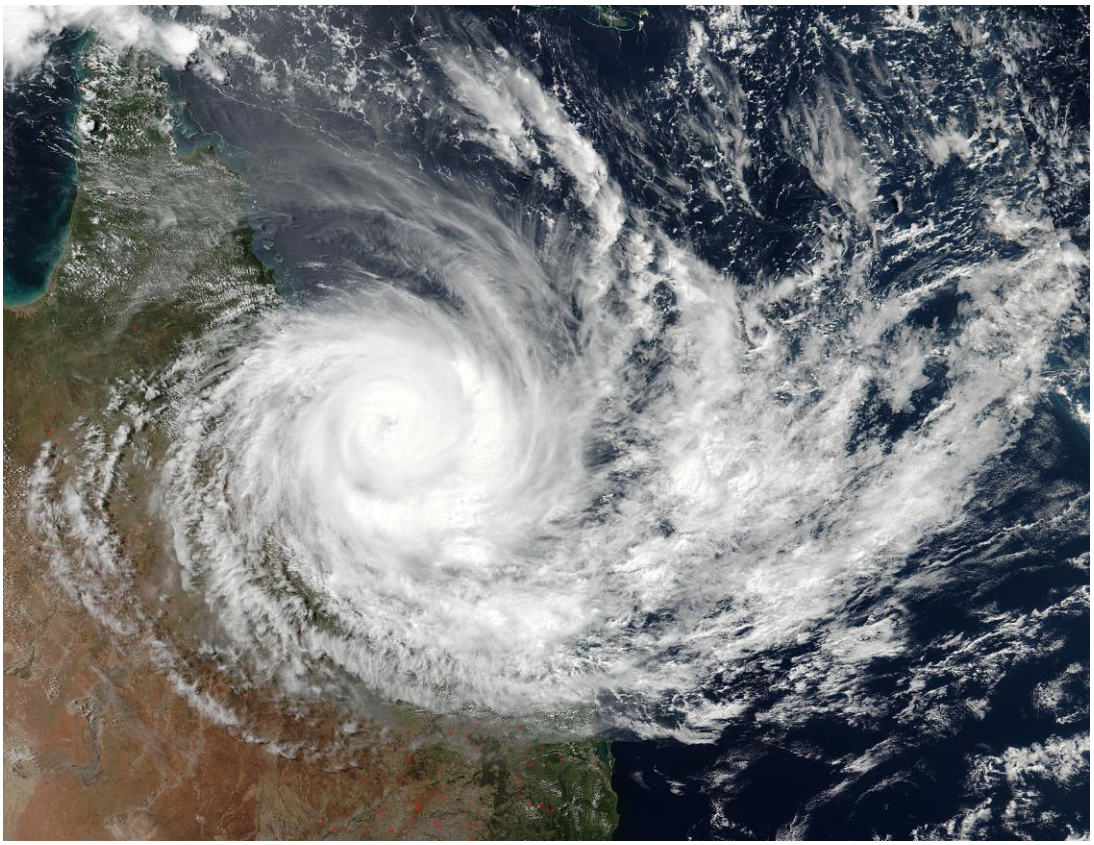
Severe Wind Hazard Preliminary Assessment

Tropical Cyclone Debbie, Whitsunday Coast, QLD, Australia

28th March 2017



(Courtesy: https://www.nasa.gov/sites/default/files/thumbnails/image/debbie.a2017087.0342.1500m.jpg)

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Rev. 1

INTRODUCTION

Severe Tropical Cyclone Debbie was a category 4 system that made landfall near Airlie Beach (Figure 1) on the north Queensland coast at midday on the 28th of March, 2017. As part of a continuing effort to better characterize wind fields that impact communities during severe wind events, the Cyclone Testing Station (with collaborators from the Wind Research Laboratory at The University of Queensland) deployed SWIRLnet (Surface Weather Relay and Logging Network) weather stations to the region prior to Debbie's landfall. Six SWIRLnet towers (3.2 m high anemometers placed in the communities likely to be affected) collected data continuously prior to, during and after landfall. Three towers were deployed in the Ayr/Home Hill region, two in Bowen and one in Proserpine (Figure 2). This Preliminary Assessment Report details the initial observations from these towers, compares these with Bureau of Meteorology Automatic Weather Station observations, and makes some preliminary comment on the damage to structures in storm-affected communities.

METEOROLOGICAL SYNOPSIS

The tropical low that eventually developed into Severe Tropical Cyclone Debbie formed over the North Coral Sea on 21 March approximately 125 km southeast of Papua New Guinea. It tracked to the southeast for roughly 18 hours before making a turn to the south and then southwest through 10:00 AEST on 23 March. The tropical low meandered southwest for 24 hours before making a turn to the south-southeast. On 25 March at 04:00 AEST it had intensified enough over the Coral Sea Islands to warrant an upgrade to Category 1 Tropical Cyclone Debbie.

Debbie steadily increased in strength over the next 12 hours to a Category 2 tropical cyclone and reached Category 3 status on 26 March at 04:00 AEST. At the time Debbie intensified to a Category 3 cyclone, the centre of the storm was approximately 488 km to the northeast of Ayr and was moving to the west-southwest. Debbie moved to the west-southwest for 24 hours before taking a south-southwest jog for roughly 12 hours. At 16:00 AEST on 27 March, Debbie intensified to a Category 4 cyclone approximately 213 km to the east-northeast of Bowen.

Debbie continued to meander southwest to south-southwest for the next 18-24 hours leading up to landfall as a Category 4 cyclone. Interestingly, Debbie was undergoing an eyewall replacement cycle leading up to landfall as shown in Figure 1. Commencing around 04:00 AEST on 27 March, the original inner eyewall began to decay as a concentric secondary outer eyewall began to form. Whilst Debbie moved closer to the Queensland Coast, the radius of maximum winds expanded, however, the interaction with land interrupted the eyewall replacement cycle and did not allow the inner eyewall to completely decay. Moreover, the outer eyewall never contracted fully nor did it take the place of the original inner eyewall. The disruption of the eyewall replacement cycle is likely to have impeded further intensification at landfall. Debbie made landfall around 11:50 AEST on 28 March near Airlie Beach (Figure 2) as a Category 4 cyclone, as per the Bureau of Meteorology (BoM) Tropical Cyclone Scale summarized in Table 1.

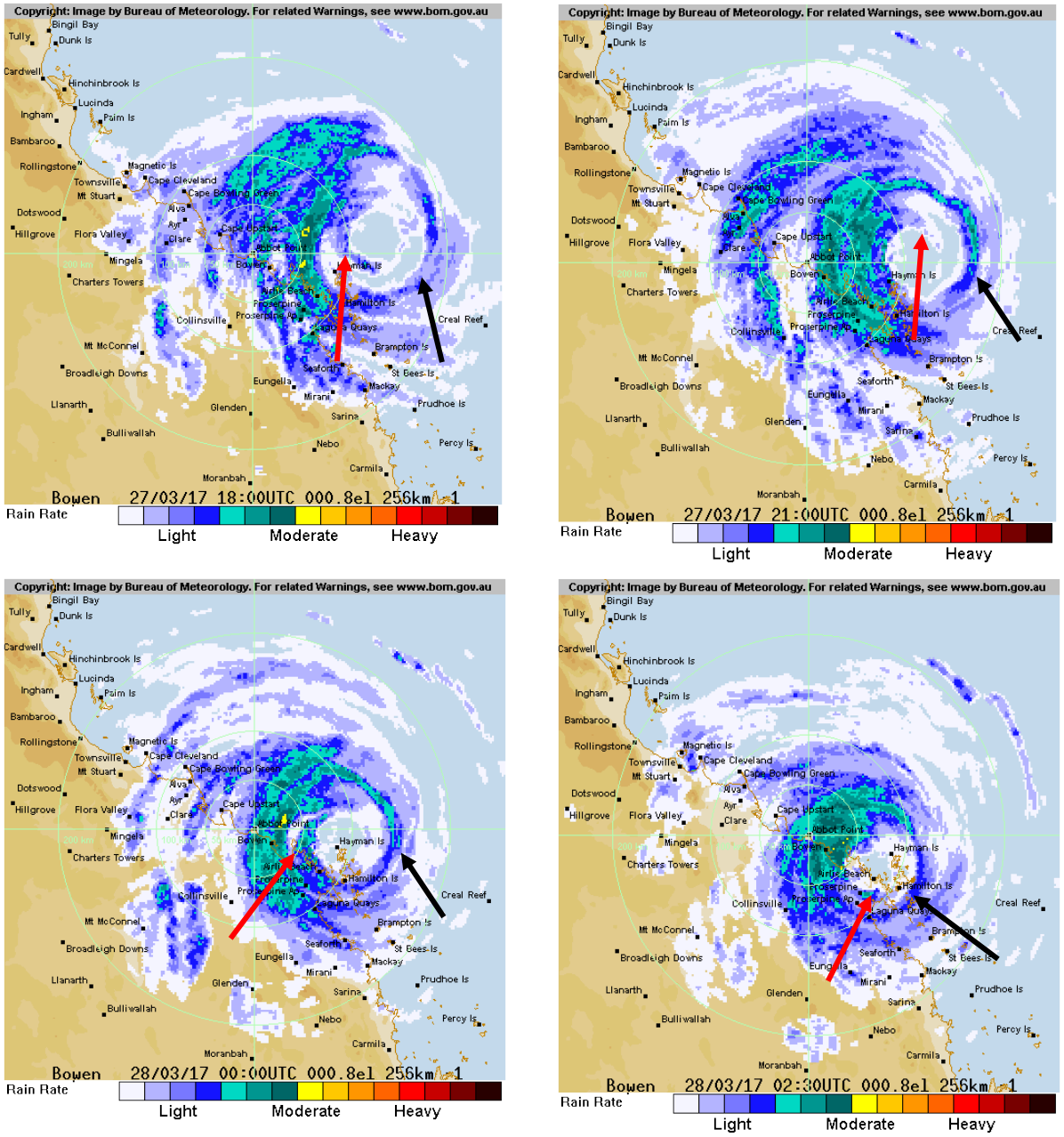

Figure 1. Bowen radar 0.8º reflectivity plan position indicator scans during the landfall of Severe Tropical Cyclone Debbie. Times are reported in UTC (+10 UTC to convert to AEST). Red and black arrows point to the inner and outer eyewalls respectively.

Figure 2. Best track for Severe Tropical Cyclone Debbie (track courtesy of the Joint Typhoon Warning Center). Dates and times are in Australian Eastern Standard Time.

Table 1. Australian tropical cyclone intensity scale in km/hr.

Cyclone Category	Australia Bureau of Meteorology	
	10-min Sustained	3-sec Gust
Category 1	63-88	91-125
Category 2	89-117	125-166
Category 3	118-157	167-225
Category 4	158-198	226-280
Category 5	>198	>280

SWIRLnet OBSERVATIONS

This section includes preliminary analysis of wind and pressure data from the Cyclone Testing Station's SWIRLnet portable anemometers. The team deployed six anemometers (Towers 1 to 6) from Ayr to Proserpine (Figure 2). Each tower has an RM Young propeller anemometer mounted at 3.2 m height to measure wind speed and direction, a Vaisala pressure transducer and a CSL shrouded temperature and relative humidity sensor mounted at 1 m. All towers record wind data locally at 10 Hz, with 10 minute summary data files sent to an FTP (file transfer protocol) site via mobile internet networking cards. SWIRLnet anchor sites were graciously provided by the Whitsunday Shire Regional Council and Burdekin Shire Council.

A brief description of each deployment site is provided below.

- Tower 1 was located in an open field showground ~1 km west of Ayr near an industrial estate. Winds from NE through SW will have travelled over Ayr before reaching the site, and winds from the NW will be influenced by the industrial site.
- Tower 2 was deployed in a park within Queens Park in Bowen. The ocean is approximately 500 m to the NE of the site, with moderately spaced suburban buildings to the NW and SE.
- Tower 3 was located on a sports field at the southern edge of Ayr. A golf course is to the east of the site with variable length fetches of suburban terrain throughout all other directions.
- Tower 4 was located on a sports field south of Home Hill. The site has suburban exposure from the town for winds from the NW quadrant but is open exposure in all other directions.
- Tower 5 was deployed to a vacant block of land a few hundred metres from the beach in the southern part of Bowen. As such, winds with a strong southerly component will be heavily influenced by marine exposure, while those from the north will be influenced by the suburban exposure of Bowen itself.
- Tower 6 was placed in a park south of Proserpine. The immediate site is open terrain in all directions, but winds with a northerly component will be influenced by the town.

Table 2 lists the maximum 3-second gust wind speed recorded at each of the SWIRLnet sites as well as by the Bureau of Meteorology Automatic Weather Stations. Minimum atmospheric pressures are also indicated. Of the SWIRLnet towers, the highest gust was recorded at Tower 5 in Bowen, 125.7 km/h with the minimum central pressure recorded at the Proserpine site, Tower 6, 962 hPa.

Table 2. Wind, pressure, and measurement site information for SWIRLnet and Bureau of Meteorology automatic weather stations during Severe Tropical Cyclone Debbie on 28-29 March 2017.

Site	Max 3s Gust [km/h]	Direction (°)	Time [20/3]	Tower height [m]	Lowest P [hPa]
Tower 1 (Ayr)	59.4	245	28/13:00	3.2	992.0
Tower 2 (N. Bowen)	108.9	230	28/13:00	3.2	972.0
Tower 3 (Ayr)	55.5	240	28/13:00	3.2	992.0
Tower 4 (Home Hill)	63.9	240	28/15:00	3.2	990.0
Tower 5 (S. Bowen)	125.7	270	28/13:30	3.2	971
Tower 6 (Proserpine)	97.1	235	28/12:00	3.2	962.0
Bowen Airport (BoM)	148	247.5	28/14:30	10	972.2
Hamilton Island (BoM)	263	292.5	28/10:30	10	966.3
Mackay (BoM)	95	90.0	28/14:00	10	993.0
Mackay Airport (BoM)	98	22.5	29/02:15	10	998.8
Proserpine (BoM)	165	135.0	28/13:00	10	969.0

Figures 3-11 provide detailed time-history data for each of the SWIRLnet anemometer Towers 1-6. This is raw data that is yet to be fully analysed and validated. No corrections have been applied that would adjust measured speeds to a standard 10 m elevation or open exposure.

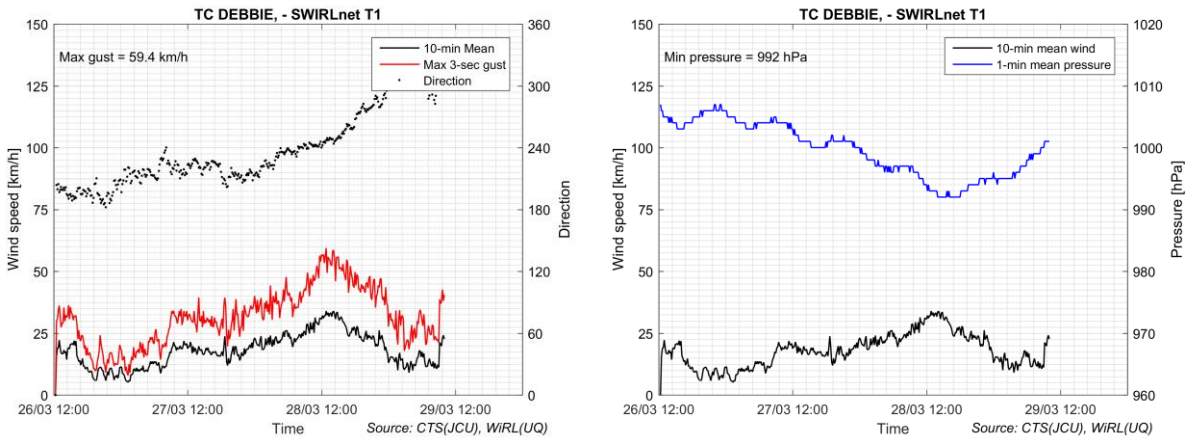

Figure 3. SWIRLnet Tower 1 (Ayr) wind and pressure data from 12pm 26th march to 12pm 29th March. **Left:** 10-minute mean and speed, 3-second gust and wind direction. **Right:** 10-minute mean wind speed and 1-minute mean atmospheric pressure.

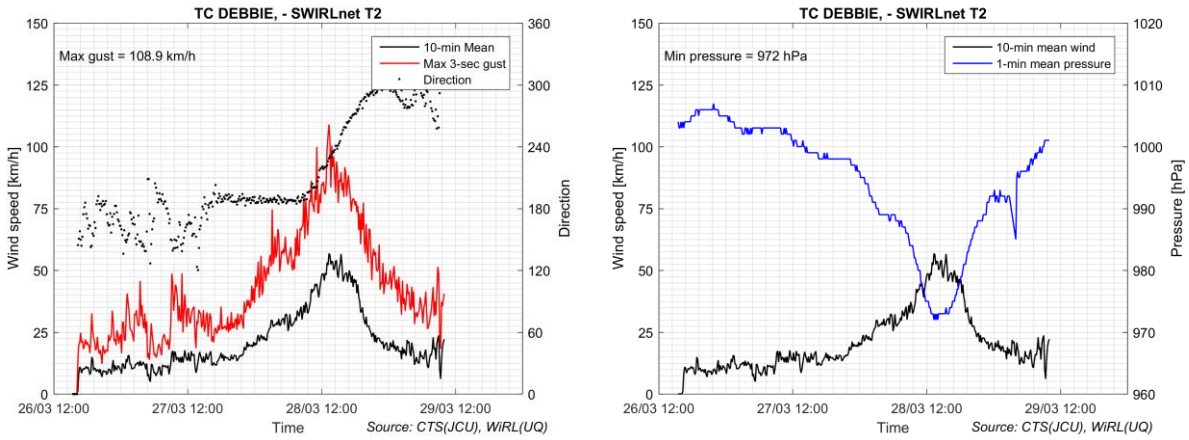

Figure 4. As for Figure 3, but Tower 2 (South Bowen)

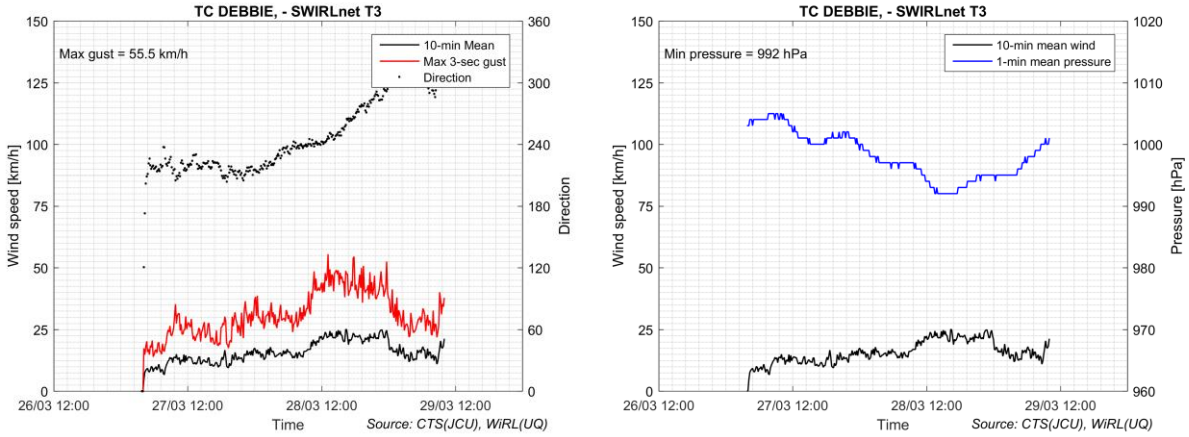

Figure 5. As for Figure 3, but Tower 3 (Ayr)

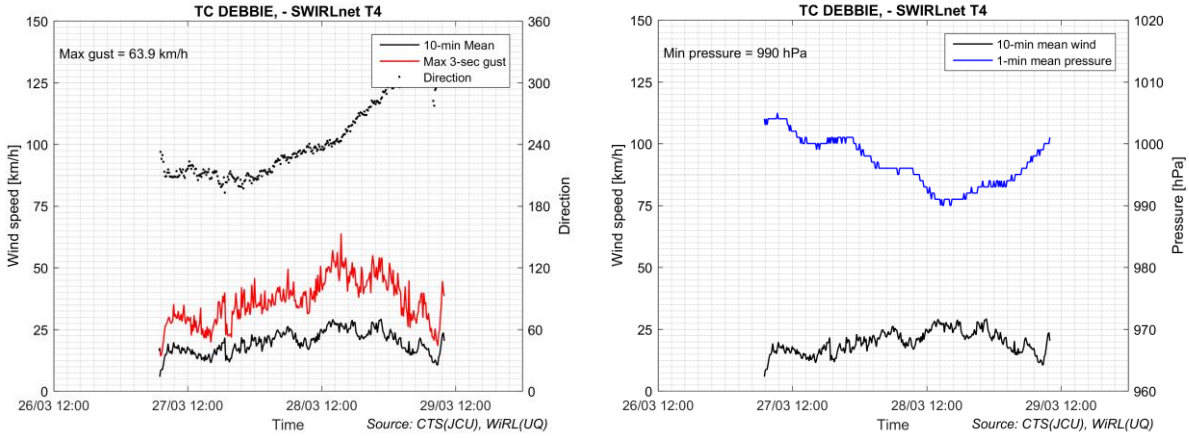

Figure 6. As for Figure 3, but Tower 4 (Home Hill)

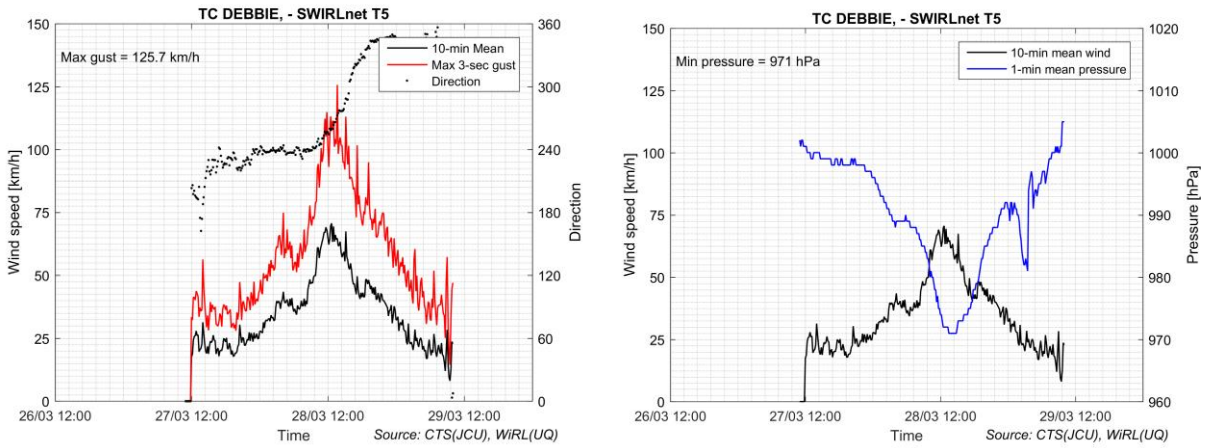

Figure 7. As for Figure 3, but Tower 5 (South Bowen)

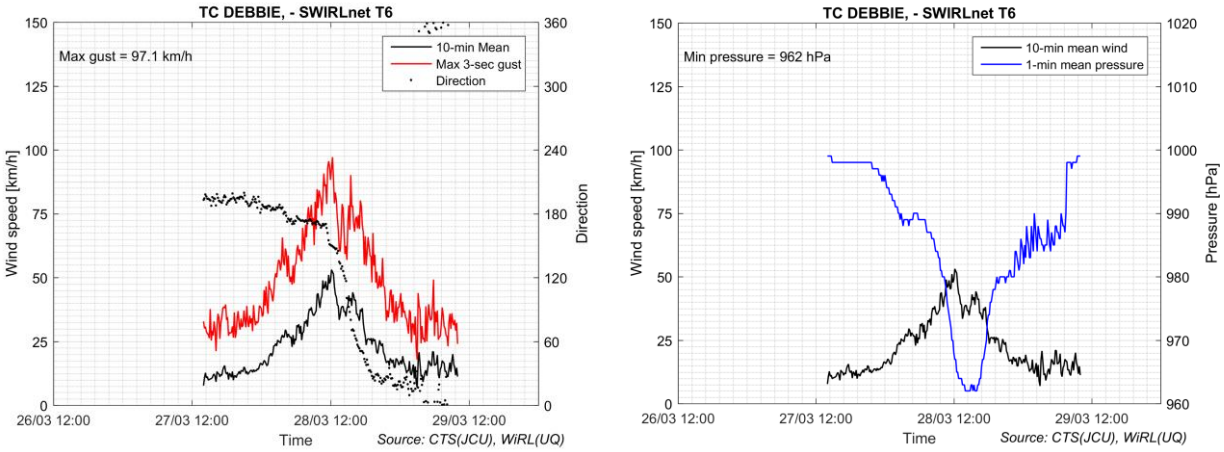

Figure 8. As for Figure 3, but Tower 5 (Proserpine)

AUSTRALIAN BUREAU OF METEOROLOGY OBSERVATIONS

Figure 9 provides maximum three-second gust wind speed time histories for five Bureau of Meteorology automatic weather stations: Bowen Airport, Hamilton Island, Mackay, Mackay Airport, and Proserpine. This figure is generated using data drawn directly from the Bureau's real-time data feed and is yet to be confirmed by the Bureau of Meteorology. Their more detailed analysis of the automatic weather station data may involve correction for calibration factors of each instrument and establishing whether the reported data was influenced by local topography and/or terrain.

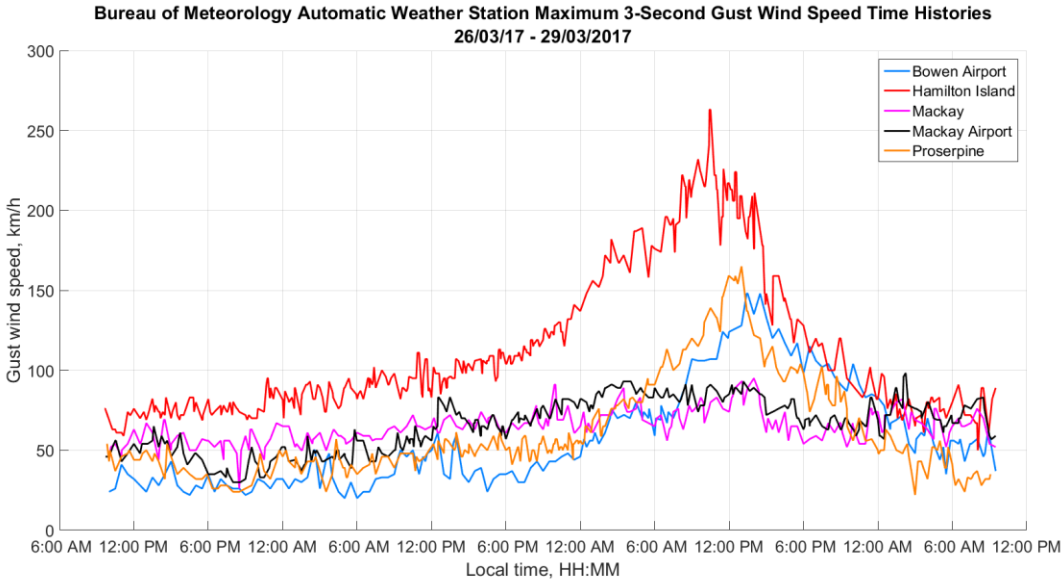

Figure 9. Bureau of Meteorology automatic weather station maximum three-second gust wind speed time histories recorded during the landfall of Severe Tropical Cyclone Debbie.

The Hamilton Island AWS recorded the highest gust at a BoM site, with a magnitude of 263 km/h. While this wind speed exceeds the design wind speed for the region, ocean exposure and its siting on a hill mean these readings are considerably (order 30%) higher than what would be measured over standard flat, open (land) terrain, as assumed by the Australian wind loading standard (AS/NZS 1170.2). The maximum wind gust measured over the mainland was 165 km/h at Proserpine Airport.

A point of note when comparing SWIRLnet measurements to BoM AWS records is that the lower elevation of SWIRLnet towers (3.2 m) compared with AWS towers (10 m) will lead to lower wind speeds being measured by these stations. This magnitude difference occurs due to a higher degree of roughness (e.g. from trees, buildings, etc.) near ground level, which generally decreases mean wind speed and increases turbulence intensity. The actual ratio between wind speeds at these two elevations varies for different site conditions, but can be of order 30%.

AUSTRALIAN DESIGN STANDARD

The affected region (Bowen, the Whitsundays, Airlie Beach, Proserpine, and Mackay) is in wind Region C (within 50 km of the coast) as defined in AS/NZS 1170.2 and shown in Figure 10. The regional design gust wind speed in standard conditions for typical (Importance Level 2) buildings is 248 km/h (69 m/s, 154 mph). Residential structures designed in Queensland since the mid-1980s are required to be designed to resist wind pressures corresponding to this ultimate wind speed. For example, at Proserpine the AWS recorded a maximum three second gust of 148 km/h (Table 3) which equates to ~75% of the design ultimate wind speed for residential buildings in that location (allowing for the conversion of three-second gusts to design wind speeds).

Table 3. Ultimate design regional wind speeds by region for 1/500 annual probability appropriate for housing and other Importance Level 2 structures. Note: regions C and D include an additional uncertainty factor for the prediction of design wind speeds in cyclonic areas

Regions	V_u (m/s)(mph) AS 1170.2:1989	V_{500} (m/s)(mph) AS/NZS 1170.2:2002	V_{500} (m/s)(mph) AS/NZS 1170.2:2012
A	50 (112)	45 (101)	45 (101)
B	60 (134)	57 (128)	57 (128)
C	70 (157)	69 (154)	69 (154)
D	85 (190)	88 (197)	88 (197)

(Source: Australian Standard AS 1170.2:1989 to AS/NZS 1170.2:2012)

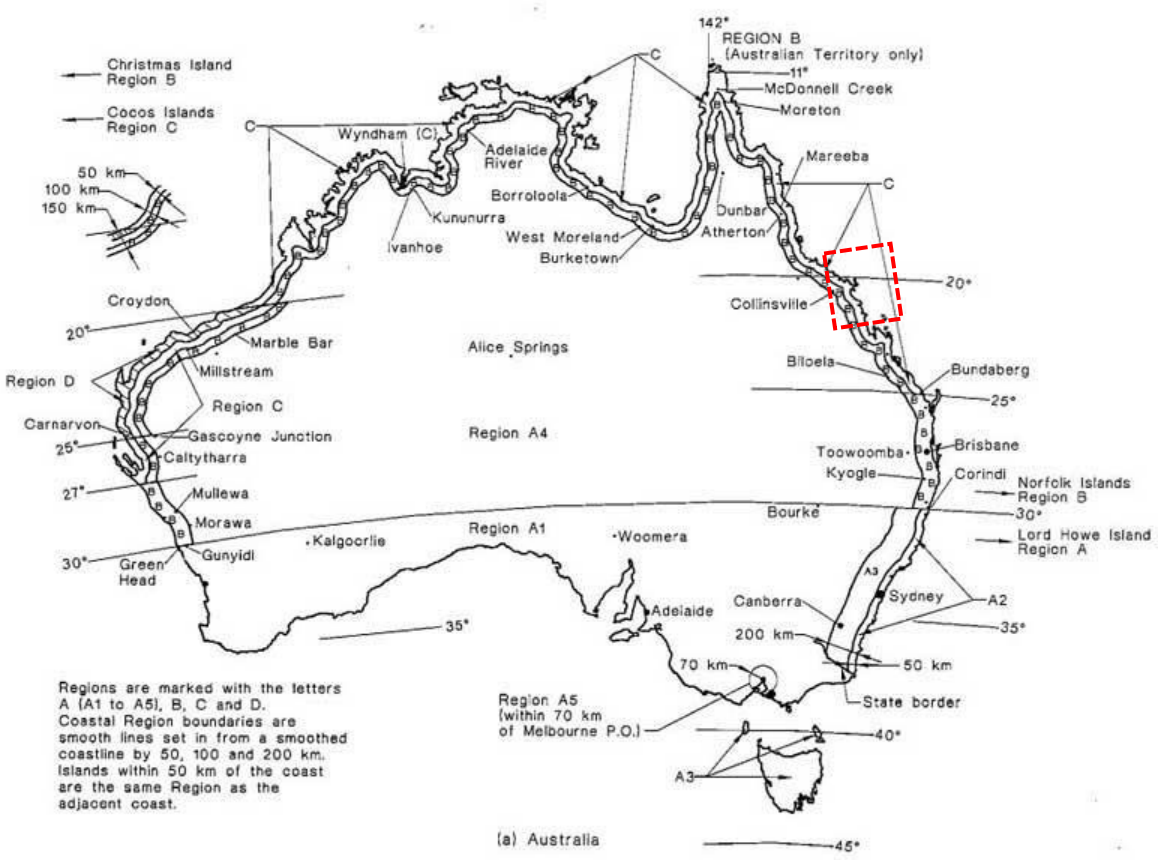

Figure 10. Design wind speeds for Australia based upon AS 1170.2 (2002). The region impacted by Tropical Cyclone Debbie (highlighted by the rectangle) has a design wind speed of 69 m/s (248 km/h, V0.2) in Region C.

OBSERVED DAMAGE

The following sections present a preliminary assessment of damages in the affected areas with examples based on media images available online soon after the event. It should be noted that this is a preliminary assessment of damage strictly from online sources and that many reports of damage may not be available online due to loss of power and mobile data coverage. A comprehensive on-site damage investigation of impacted areas is currently underway by the CTS/UQ team. A more thorough report on damage will be provided once the investigation is completed.

Cases of structural damage (Figures 11-20) were reported in Bowen, Airlie Beach and Proserpine where observed wind speeds were highest. The majority of severe damage was found in Hamilton Island and Airlie Beach although several cases of major structural damage also occurred in Bowen. These include damage to roof cladding and failure of the supporting roof framing connections (e.g., batten to rafter connections) for light framed timber housing. Water ingress damage was also observed and is expected to be a key contributor to overall losses from this event. Roof detailing (e.g., fascia, guttering, etc.) damage of modern strata buildings (i.e. multi-family units) was also recorded. Minor wind-related damages were reported in Mackay. As noted by previous CTS research with Suncorp, minor damages (e.g., guttering, fencing, outdoor furniture, etc.) can contribute significantly to total losses due to a high frequency of occurrence. Examples of minor damages are included in Figures 21-25.

Figure 11. Structural failure of batten to rafter connections supporting metal cladding of an older high-set timber framed house (Bowen).
http://www.brisbanetimes.com.au/queensland/bowen-units-damaged-but-still-standing-after-cyclone-debbie-20170328-gv8ny8.html

Figure 12. Failure of roof cladding and support connections due to severe wind loading (Bowen)
http://www.brisbanetimes.com.au/queensland/bowen-units-damaged-but-still-standing-after-cyclone-debbie-20170328-gv8ny8.html

Figure 13. Large section of metal cladding (and possibly batten) failure in Bowen. Solar panel connections appear to have performed well.
http://www.news.com.au/technology/environment/destruction-caused-by-cyclone-debbie-revealed-on-wednesday-morning/news-story/b25eab2c1d771250cf05c9eac55ba3d1

Figure 14. Damage to metal cladding resulting in water damage to a ceiling in Hamilton Island
https://au.news.yahoo.com/a/34817344/cyclone-debbie-continues-to-weaken-after-unleashing-on-mainland-queensland-hitting-bowen-after-smashing-whitsundays/#page1

Figure 15. Loss of roof battens and cladding for a three storey unit on Hamilton Island
https://www.facebook.com/7NewsBrisbane/photos/pcb.1462910670388447/1462908637055317/?type=3&theatre

Figure 16. Complete loss of roof cladding and structure of a resort unit on Hamilton Island (likely) due to failure at roof to wall connections
https://www.facebook.com/7NewsBrisbane/photos/pcb.1462910670388447/1462908587055322/?type=3&theater

Figure 17. Failure of roof structure in the edge region for a modern apartment unit in Airlie Beach
http://www.news.com.au/technology/environment/destruction-caused-by-cyclone-debbie-revealed-on-wednesday-morning/news-story/b25eab2c1d771250cf05c9eac55ba3d1

Figure 18. Failure of a canopy roof near Shute Harbour near Airlie beach
http://www.abc.net.au/news/2017-03-29/cyclone-debbie-bom-downgrade-fears-mount-for-queensland-towns/8393914

Figure 19. Failure of a large sliding door in Airlie Beach possibly due to internal pressurization following failure of the window in the windward wall (on the right in the photo)
https://twitter.com/JonathanHair/status/846855448485490689/photo/1

Figure 20. Failure of a timber frame carport in Airlie Beach
https://www.facebook.com/photo.php?fbid=10154553764652106&set=pcb.402653330100939&type=3&theater

Figure 21. Damage to fencing and gates in Airlie Beach (typical)
https://www.facebook.com/photo.php?fbid=10154553764737106&set=pcb.402653330100939&type=3&theater

Figure 22. Damage to fencing in Proserpine
https://www.facebook.com/photo.php?fbid=10155041909386000&set=pcb.10155041917071000&type=3&theater

Figure 23. Damage to outdoor furniture in Mackay
https://m.dailymercury.com.au/photos/cyclone-debbie-damage-in-mackay-region-2/50211/#/23

Figure 24. Damage to shed in Mackay
https://m.dailymercury.com.au/photos/cyclone-debbie-damage-in-mackay-region-2/50211/#/28

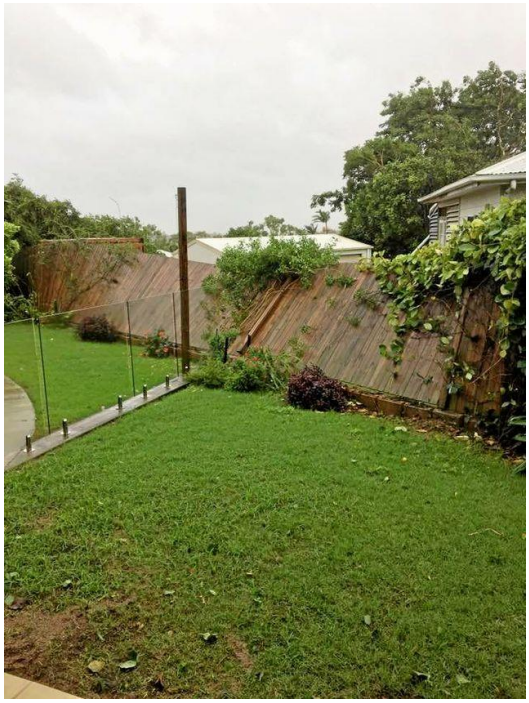

Figure 25. Damage to fencing in Mackay
https://m.dailymercury.com.au/photos/cyclone-debbie-damage-in-mackay-region-2/50211/#/23

ACKNOWLEDGEMENTS

This report was prepared from onsite and media-sourced content by the engineering faculty and students at Cyclone Testing Station (James Cook University) the University of Queensland and University of Florida. The study compliments experimental research at these institutions seeking to characterize extreme wind events and their impact on buildings. The purpose of the report is to provide a preliminary engineering assessment of severe weather events, within the first 24 to 48 hours. As a result, much of the information is necessarily collated from immediately available sources (i.e. social media, local news outlets, weather agencies, etc.). A more detailed report drawn from information field investigations will be released later.

Please visit https://www.jcu.edu.au/cyclone-testing-station/swirlnet for additional information, and for access to previous rapid assessment damage reports. Questions and comments on any aspects of our work are most welcome. Please direct your enquiries to Dr. Daniel Smith (daniel.smith8@jcu.edu.au) at the Cyclone Testing Station.

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