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Tornadic Waterspout Impacts on Coastal Australia

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Abstract

Surveyed damage using the Enhanced Fujita Scale is presented for a recent tornadic waterspout event at Kurnell in NSW.

Recent tornadic events at Kurnell, Kiama and Lennox Head in coastal New South Wales formed either wholly or partly offshore. It is proposed that a warm, moist layer of air at the sea surface creates more unstable atmospheric conditions than would an approaching supercell path over land, and hence a greater propensity to generate a tornadic event.

Measured and observed wind velocities in the vicinity of 60 ms^{-1} associated with the observed tornadic waterspouts are considerably higher in magnitude than the basic wind speed presented in AS1170.2 for an estimated return period of 2000 years in Region A.

Introduction

Fair-weather waterspouts are intense low pressure vortex columns that most frequently develop on the sea surface lasting from two to twenty minutes. The funnels occur most frequently in the tropics and sub-tropics where heated, humid air creates strong convective currents. These are regularly sighted off the Australian coastline, usually dissipate at sea and cause little damage if reaching shore (less than EF0 on the Enhanced Fujita scale), Figure 1.

Figure 1: Fair weather waterspout sighted by first author off the coast of North Curl Curl, Sydney (2013).

A less common and more intense form of waterspout is the tornadic waterspout. Supercell thunderstorms containing persistent mesocyclones and updrafts form tornadoes and those formed over a body of water are tornadic waterspouts. Recent examples of tornadic waterspout occurrences in New South Wales (NSW) included one at Lennox Head during June 2010 as documented by Glanville & Quinn (2010), at Kiama in 2013, and at Kurnell in 2015.

Kurnell, NSW experienced tornadic supercell winds on 16 December 2015 as described by Krupar, Mason and Glanville (2016). The supercell originally formed near Port Kembla, NSW approximately 60km to the southwest. For the next two hours, the supercell continued to evolve as it tracked north-northeast along the coast of NSW toward Kurnell. Rapid intensification was observed at 9:19am; a clear hook-echo is also evident in rain radar reflectivity scans signifying localised rotation.

It is proposed the supercell coastal path line itself contributed to the formation of a tornadic waterspout at Kurnell. A warm, moist layer of air at the sea surface creating more unstable atmospheric conditions than would an approaching supercell path over land.

Kurnell Damage Survey

Following the Kurnell storm, several damage surveys were undertaken by Krupar, Mason and Glanville (2016) to assess damage incurred to the built and natural environments in Kurnell. Surveys were carried out in the worst affected areas with notional Enhanced Fujita Scale (EF-Scale) damage categories assigned to buildings based on observable damage from the street. Figure 2 highlights the streets and paths surveyed by both teams as accessed by car and mountain bike. The surveys were conducted during the afternoons of 17th, 18th and 24th of December 2015. Photographic evidence and aerial photography in the media was also reviewed as part of the survey activities.

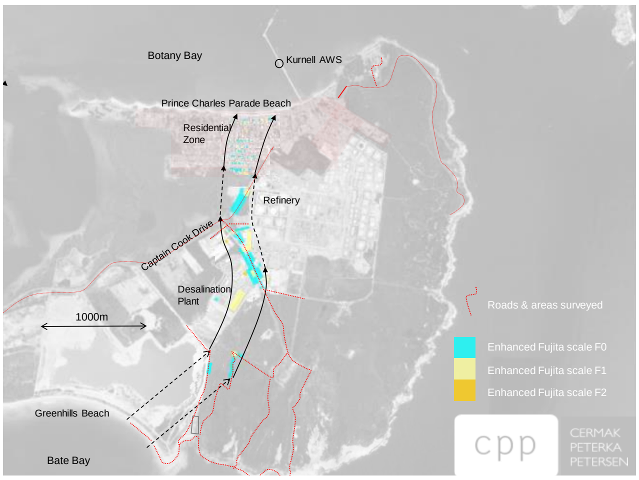

Figure 2: Estimated damage swathe and associated EF-scale damage ratings assigned to surveyed buildings, Kurnell.

Inspecting damage to structures throughout the Kurnell region revealed a swathe of about 200-250 m wide aligned north-south between the desalination plant and Botany Bay. Examples of damage observed to residential and commercial structures are provided in this paper and Figure 2 maps all observed damage rated against the Enhance Fujita (EF) scale. Damage generally being assigned an EF0 or EF1 rating, and some isolated EF2 damage.

Based on analysis of radar data the supercell looked to have approached from the southwest over Bate Bay, although there was little observed evidence of scouring or vegetation damage within the dunes of Greenhills Beach.

A small seaside hamlet comprising lightweight sheds and caravans is outlined by a rectangle in Figure 2. Residents reported seeing a tornado vortex pass to their west, thankfully missing their shelters. Moving northward into bushland there was clear evidence of tree damage, denuded and broken tree trunks and limbs.

Continuing north, the desalination plant lost metal deck sheeting over much of its roof plan with roof sheeting and insulation found deposited hundreds of metres from the plant. Distinct signs of multidirectional flow can be observed in Figure 3, where roof sheeting from the desalination plant is seen deposited on all sides of the plant building. A clear swathe of sheeting is shown to the south (lower left) of the plant. This is the opposite direction to the movement of the storm.

Much of Sir Joseph Banks Drive was littered with debris from this and other buildings (Figures 4).

Figure 3: Debris from the desalination plant and its surrounding buildings captured by the Westpac Lifesaver Rescue Helicopter.

Industrial units in the direct path suffered façade breaches including broken windows and lifted roof sheeting. On Chisholm Road a lorry was blown over onto an adjacent and thankfully empty parked car (Figure 5). As the tornado continued northwards crossing Captain Cook Drive it passed over roadside high voltage transmission lines, but no damage was evident to these structures. Similarly, no obvious damage could be sighted to the refinery east of Captain Cook Drive.

The tornado passed directly over the residential township of Kurnell northward to Botany Bay, Figure 6. Inspecting damage in the residential zone was reminiscent of surveying water spout damage in Lennox Head 2010, with damage confined to a finite width outside of which little permanent damage could be observed. Roof damage was common to homes in the damage swathe, with lifted roof sheeting, and missing tiles, and removed solar panels.

Figure 4: Debris from the desalination plant and other surrounding buildings on Sir Joseph Banks Drive, Kurnell.

Figure 5 Damage to industrial building on Chisholm Road, Kurnell, with overturned truck in foreground.

Figure 6: Damage to a residential home in the Kurnell township.

Temporary structures were also displaced (e.g. garden sheds, awnings, a trampoline and fallen trees). A video of the swathe was captured by a drone flight (see Dailymail 2015 weblink)

The Insurance Council of Australia (2016) reported 4282 claims with total insured losses of $202 million. The highest number of claims was from homes; however 72% of the insurance losses were commercial.

Measured and Observed Tornadic Waterspout Wind Speeds

As the Kurnell tornadic supercell continued moving north-northeast beyond the Kurnell township, in a rare occurrence it passed over the Bureau of Meteorology (BoM) Automatic Weather Station (AWS) located on a wharf jetty north of Kurnell. A maximum three-second gust wind speed of 213 km/hr (59ms^{-1}) was recorded at 14 m above the water level. This was the strongest wind gust ever recorded by a BoM AWS station in NSW.

Wind speed was not measured during the Lennox Head tornadic waterspout; however captured video footage of the event is available in the public domain (Glanville & Quinn (2010)). Inspection of the video footage and triangulation against some Lennox Head landmarks provided an estimate of wind velocities reaching 65 ms^{-1}. Observed damage ranged from EF0 to EF2 and was observed to be comparable to the Kurnell storm. By contrast the width and length of the damage swathe at Lennox Head was approximately 25% that of the Kurnell Storm.

Kiama 2013 was part of the Sydney-Illawarra tornado outbreak 23–24 February 2013. The Illawarra storms, between Seven Mile Beach and Nowra including Kiama were rated F2 with reported wind speeds of up to 200 km/h (55 ms^{-1}); post event analysis confirmed eight tornadoes, with two rated F0, five at F1 and one rated as F2 (Allen 2016). Sydney tornadoes of lesser strength reported to have caused damage were at Kirribilli, Chifley, Malabar and Randwick.

Property damage at Kiama was similar to that in the Kurnell and Lennox Head events, based on media reports and verbal discussions with Kiama residents by the first author. Figure 7 illustrates a home re-build still in construction almost three years after the event. The waterspout was reported to have come off the ocean causing damage to properties on the hill crest (camera location) before continuing south then inland toward Jamberoo.

Figure 7: Hothersal Street, Kiama photo taken January 2016.

Also reported in the media; May 2010 a water spout is known to have caused damage to a caravan park at The Entrance in central NSW with recorded injuries. In August 2006 a water spout was filmed ripping the roof off a house in La Perouse.

A database of tornado and waterspout events is available through the BoM Storm Archive (2016), and contains some characteristics of each event as well as comments indicating the extent of damage caused and in some cases a wind speed or Fujita scale rating. The immediate usefulness of this database for the identification of temporal or spatial trends is limited, since tornado observations are necessarily observed more frequently in locations with higher population density. In addition, population density has varied significantly over the duration of the historic record.

The general distribution approximately matches the population centres of the Australian territory, Figure 8. A similar figure results from a plot of waterspout records, but without inland matches. Some of the tornadic events are located on the coastline, and it is evident that classification error is possible for tornadoes.

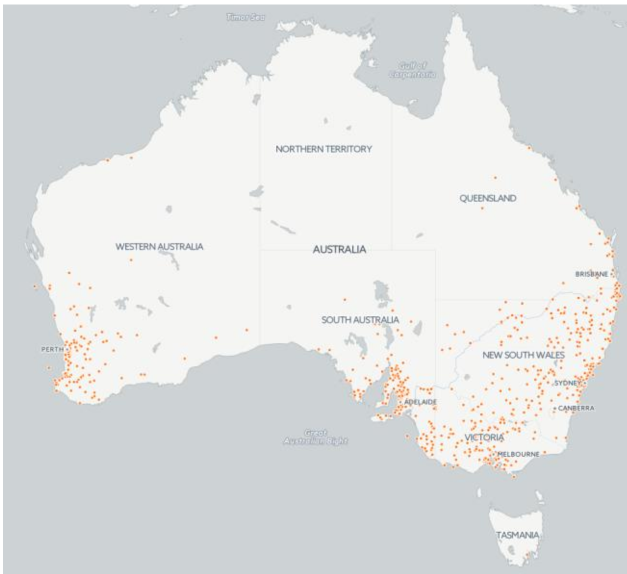

Figure 8: BoM tornado records 1795-2016 represented as orange dots

Tornadic Waterspout Return Period

Damaged area estimates for the tornadic waterspout events in Table 1 were taken from Glanville & Quinn (2010) and Krupar, Mason and Glanville (2016). For Kiama an estimate is made from the BoM Storm Archive (2016) and media clips.

Table 1: Damage area estimates on NSW coast due to tornadic waterspouts over the last five years

Date	Town	Damage	Measured or estimated max wind speed (ms^{-1})	Area of recorded damaged (m^2)
03/06/10	Lennox Head	EF2	65	35,000
24/02/13	Kiama	EF2	60	60,000
16/12/15	Kurnell	EF2	59	546,000

The authors are unaware of other waterspout events which have caused EF2 damage, with the exception of a waterspout in 1929 near Brisbane reported in BoM Storm Archive (2016), which resulted in significant destruction of the suburb of Manly, although details are limited. Lack of such events older than about five years may indicate the existence of a recent trend for increased waterspout activity on the Australian temperate coastline.

A simplified tornado hazard probability model credited to Thom (1963) uses a geometric interpretation of probability. Tornado strike probability P(s) is:

$$P(s) = \frac{\bar{a}u}{A} \quad (2)$$

Where $\bar{a}$ is the mean damage path area, u is the mean number of tornadoes per year in a local region and A the area of the local region. The model assumes a uniform distribution of tornado hazard across the region.

The three known EF2 events in Table 1 occurred in a period little over 5 years, i.e. u = 0.54 occurrences per year with velocity in the order 60 ms^{-1}.

It is proposed the impact of tornadic waterspouts is limited to a narrow band of coastal strip following the shoreline and extending inland by 500m; an indicative distance for a waterspout to travel inland.

The stretch of coastline under consideration extends between Kiama and Lennox head, a sizeable portion of the NSW coastline. The total length of coastline between these two points is approximately 729 km, measured to a resolution of approximately one kilometre. Locations where damage due to tornadic waterspouts could conceivably have been observed and reported would generally be limited to inhabited and developed portions of the coastline. This coastline length was measured by evaluating aerial imagery of the total coastline stretch at a similar resolution to a distance inland of about one kilometre, and was found to be approximately 394 km with the majority of development between Kiama and Nelson Bay north of Newcastle. The coastal strip observation area is therefore assumed to be the 394 km stretch of inhabited, or otherwise developed, coastline multiplied by a distance inland of 500 m; an area $A = 1.97\text{x}10^8\ \text{m}^2$.

With reference to Table 1 and equation (2), the strike probability is calculated to be $5\text{x}10^{-4}$, or a return period of about 2000 years. Measured and observed wind velocities in the order of 60 ms^{-1} are considerably higher than the basic wind speed presented in AS1170.2 (2011) for Region A being 48 ms^{-1} for a return period of 2000 years.

Conclusions

Whilst there are a large number of tornadoes on historic record across Australia, in recent years there could be a spatial concentration of tornadic events confined to a narrow coastal strip in the temperate zones of Australia.

Recent tornadic waterspout events at Kurnell, Kiama and Lennox Head in coastal New South Wales are thought to have formed either wholly or partly offshore. It is proposed that a warm, moist layer of air at the sea surface creates more unstable atmospheric conditions than would an approaching supercell path over land, and hence a greater propensity to generate a tornadic event.

Measured and observed wind velocities in the vicinity of 60 ms^{-1} associated with the observed tornadic waterspouts are considerably higher in magnitude than the basic wind speed presented in AS1170.2 for an estimated return period of 2000 years.

Acknowledgments

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