High Resolution Observation of a Small Tornado, Ardmore, New Zealand.

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Abstract

The University of Auckland Atmospheric Physics Group has operated mobile X-band radars for two decades. On 25 June 2005 the radar observed a small (F0) multiple tornado system passing over Ardmore in South Auckland. Reflectivity data from the tornadoes are of sufficiently high resolution to discern the wall structure and eye, track the tornadoes' path and estimate the rotational velocity of the tornado and hence the core pressure drop. The additional value of radar at very high spatial and temporal resolution is illustrated.

1. Introduction

The use of radar to observe precipitation is well established, dating as far back as the 1950s. Many countries, including New Zealand (Crouch 2003), have national networks of long-range high-power radars which are used in support of numerical weather prediction, nowcasting, aviation safety and flood management (Crum and Alberty 1993, Cheze 2002). Although networks such as these are beneficial due to their extensive coverage, the observed scales are of order 1km in space and 7 minutes in time. It is clear, however, that much finer subgrid structures are embedded within the larger scales. The University of Auckland Atmospheric Physics Group (UoAAPG) has designed and built several high resolution portable X-band radar systems to investigate these finer scales. This paper details an observation of a small tornado observed in high spatial and temporal resolution during the test phase of one such radar.

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The UoAAPG radar system was designed to be highly portable. It is towable by a 4WD so that it can be moved quickly to a site of meterological interest. Many groups around the world run such mobile rain radars mounted on a variety of vehicles, often to observe tornadoes (e.g. Biggerstaff et al. 2005, Bluestein et al. 2007, Wurman et al. 1997). In the past the UoAAPG has operated several mobile weather radars mounted on an eclectic fleet of vehicles, including a van, a caravan and a quarter-size sea container.

Mobility of small weather radars is important for two reasons. Firstly, their primary use is to obtain higher resolution measurements. As the spatial resolution of the observation is related by the distance from the radar to the target and the radar's angular resolution (beam width), the closer a radar can be stationed to the target the higher the resolution. A second more pragmatic reason for mobility is to allow rapid response on timescales similar to the changing meterological situation. For example, the predecessor to the new Trailer Radar was deployed in the path of a subtropical storm, to a volcanic eruption at Mount Ruapehu and to specific catchments for detailed hydrological studies. Immobile radar systems on the other hand obviously cannot move closer to a target area meaning that unless new radars are added to the network, precipitation over sites distant from any radar are observed at relatively low spatial resolution.

2. The University of Auckland Trailer Radar

The new Trailer Radar consists of a fully articulated dish mounted on a short tower, coupled by flexible waveguide to a masthead transceiver, the outputs of which are in turn fed, along with dish direction, into a PC housed in a small operators cab. An X-band transmitter was used so that a dish small enough to be easily transportable could provide a relatively narrow beam width (1.8 degrees). The entire system is powered by either a 4 kW diesel generator or by two single phase mains connections with a UPS battery backup. A detailed description of the radar and an animation of a deployment is available online (www.rainradar.co.nz).

Figure 1: The Trailer Radar deployed in a field. Ancillary equipment in view includes an anemometer, drop counting rain gauge and satellite dish.

3. Tornado Observation: Ardmore, Auckland

Tornadoes (and waterspouts) are not uncommon in New Zealand, around 20 are reported each year, although their size and intensity are not as great as those which famously occur in parts of North America (Sturman and Tapper 1996, Christie 1986).Their occurrence within range of our high resolution radar, however, is rare and provides an interesting example of fine scale precipitation structure. During initial field trials of the Trailer Radar on 25th June 2005, a small tornado passed near to the Ardmore field station. After several hours of stratiform rainfall on 24th of June stemming from a low and its associated trough passing over the country (Figure 2), the weather cleared up during the night. A sounding taken at Whenuapai Airbase at 12:00, approximately 41 km to the Northwest of the radar site indicated conditional instability. In the morning of 25th June, several small convective cells passed over the radar before a large thunderstorm arrived at approximately 11:30. An arm of intense precipitation extended from the rear of the storm cell. By the time the arm terminus entered the radar's range it had already developed a tornadic vortex (Figure 3). After 10 minutes, approaching a range of

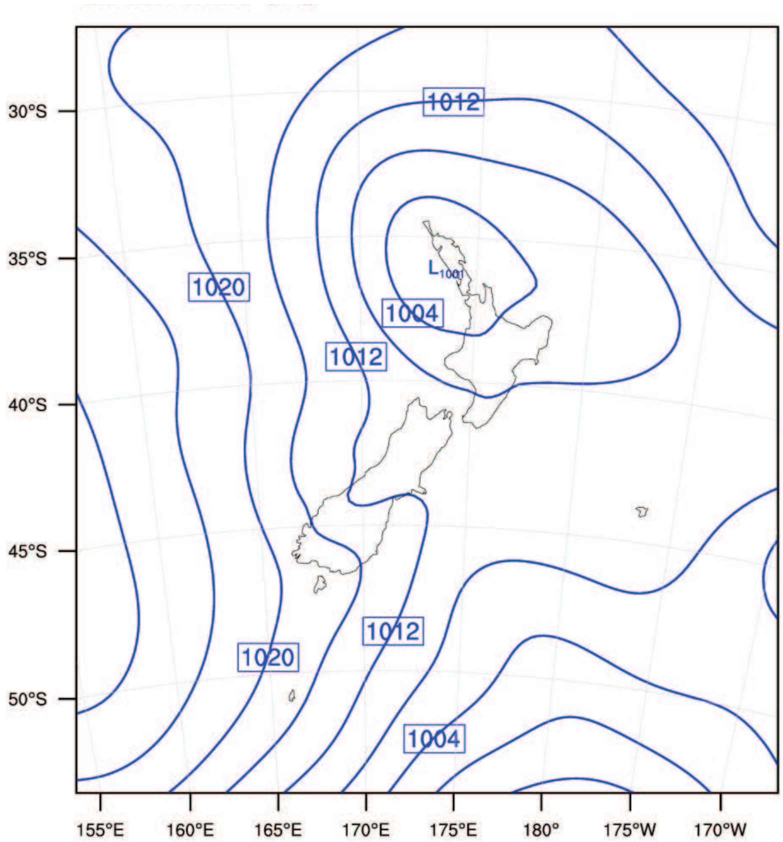

Figure 2: Mean Sea Level Pressure situation over New Zealand 2005/06/25 0000 UTC (generated with WRF-ARW from a NCEP-FNL analysis valid six hours earlier.

hills, this vortex spawned several other vortices. Only one of these persisted longer than one minute. The original vortex dissipated just before reaching the ridgeline. The second, longer lived, vortex continued in a slightly deviated path for just over 10 minutes before itself dissipating.

Although the radar is intentionally not Dopplerised, its major function being rainfall estimation, the spatial and temporal resolution is sufficiently high as to calculate the rotational velocity of the tornado by tracking the rotation of heterogeneities in the eye wall. Assuming cyclostrophic balance, the pressure drop in the tornado's eye can be estimated according to

$$p = p_o \exp\left(\frac{-w^2 r^2}{2RT}\right)$$

where p_o and T are the environmental pressure and temperature, w and r are the rotational velocity and radius of the eye wall and R is the ideal gas constant. The rotational velocity of the tornado is estimated to be of order 0.04 rad s^{-1} leading to tangential wind speeds of 70 km h^{-1}. Applying equation 1, the core pressure drop is of order 2 hPa. By way of comparison, observed pressure drops in large tornadoes can be an order of magnitude larger (e.g. Winn, Hunyady and Aulich 1999).

The calculated wind speeds associated with the Ardmore tornadoes are modest and indicate low destructive potential, F0 on the Fujita (1981) Scale. It is then unsurprising that the tornado itself did not result in widely reported damage; firefighters attended an address with a damaged roof and broken window (Kohler 2005). The tornado tracked along high tension power lines (Figure) but no significant damage was reported. The tornado also passed over two public roads and crossed the approach path to Ardmore Airport. Even weak tornadoes such as this one represent a significant aviation hazard to landing planes, as they are associated with large wind shear and loss of relative airspeed.

4. Conclusion.

It is evident that important microscale (<1 km) structure exists in mesoscale weather systems which is not well resolved by most operational observing systems. This is certainly the case for the tornado observation reported in this paper. A portable radar system such as the one recently developed by UoAAPG provides improved spatial and temporal resolution to better characterise such events.

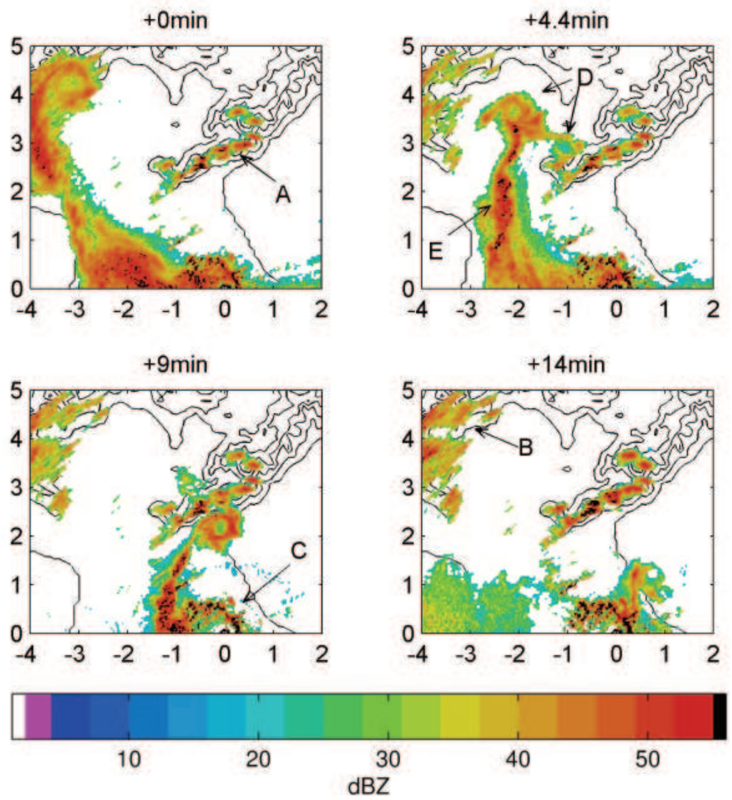

Figure 3: Radar reflectivity images of the multi tornadic system which passed over Ardmore. Contour lines (25m interval) indicate the elevation of the underlying terrain. Ground clutter creates spurious returns around the ridgelines (A and B) and near the radar (C). The system tracks from the top left to the bottom right of the frame and splits into multiple vortices (D) as it approaches a ridge. An arm of precipitation (E) extending from a large storm is associated with the vortex for the duration of the observation. An animated version is available on the UoAAPG website (http://www.rainradar.co.nz/general_examples/20050625_tornado.html)

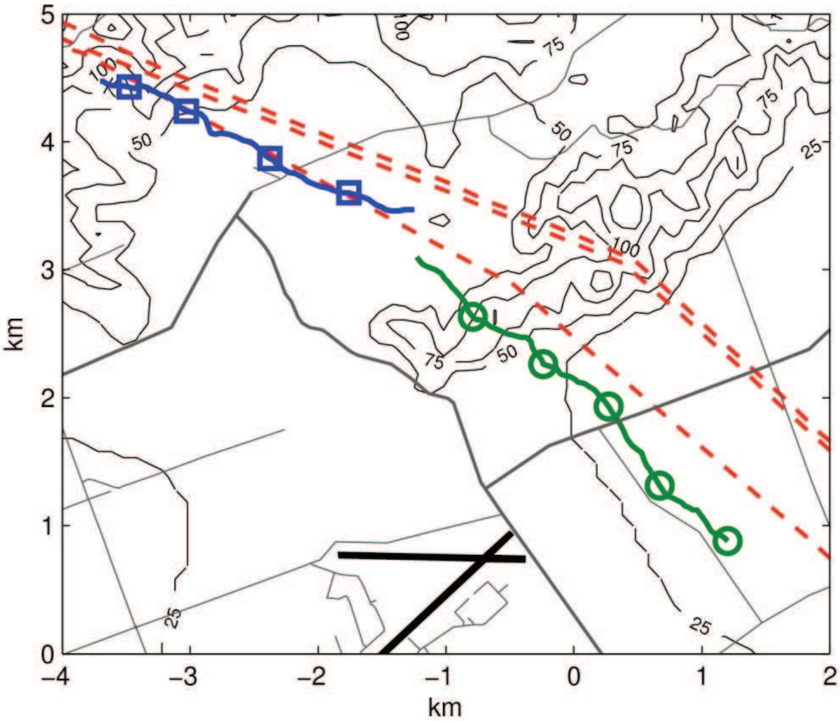

Figure 4: Tornadoes tracks over local features. The path of the first tornado is in solid blue, the squares represent the tornado position at 2.5 minute intervals starting at 11:52:30 moving from the Northwest. Around position (-1,3) the tornado breaks down into multiple vortices and spawns a new tornado which follows the solid green line, circles representing its position every 2.5 minutes. Terrain height is indicated by contours labeled in metres, roads depicted by solid gray and overhead high voltage power lines dashed red. The runways of Ardmore Airport are indicated in solid black (-1,0.5).

Acknowledgements

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