10.2 TORNADIC MINI-SUPERCELLS IN NORTHERN CANADA

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1. INTRODUCTION

Supercell tornadoes are not uncommon on the Canadian Prairies. On average, approximately 42 tornadoes (McDonald, 2005) are reported annually in this region, with supercells accounting for roughly 75% of those events. The remaining are non-supercell tornadoes, forming from weaker and, apparently, less organized convection.

On July 8, 2004, a large weather system over the western Canadian Prairies produced a wide variety of storm types including one unique tornadic event. In a cool and moist part of this environment, a line of very small thunderstorms developed and tracked from generally east to west. Persistent rotation was observed in virtually every significant cell within in this line. One of these small storms produced an F1 tornado that tracked through part of the city of Grande Prairie, Alberta (latitude 55.1˚N). However, this cell escaped detection by the sophisticated algorithms of the Weather Service's Doppler radar system. Video of photographic evidence revealed a well-formed funnel as it crossed part of the community.

Post-analysis of this event demonstrated that this small thunderstorm exhibited mini-supercell characteristics, yet was of a smaller scale than is typically attributed to this type of thunderstorm.

2. METEOROLOGICAL ASSESSMENT

The tornado occurred northwest of a “stacked” low (Figure 1) from the surface to 250 hpa. There are only 2 soundings in the area: one at Stony Plain – WSE (Figure 3) and one at Prince George – ZXS (Figure 4). Unfortunately, given their distance from the event, neither can be deemed as representative of the atmospheric profile over Grande Prairie. Therefore, the following upper air assessments are all subjective interpolations derived from the upper air charts and serve only as a rough approximation.

The surface winds at Grande Prairie were northwest at 12 knots until the time of the tornado when they veered to northeasterly 5 to 10 knots. At 00Z July 9, 2006, winds at 850 hpa were north to northwesterly at 10 knots, northeasterly 15-25 knots at 700 hpa, northeasterly 20-30 knots at 500 hpa, and northeasterly 30-40 knots at 250 hpa.

From 18Z to 21Z, there appeared to be a surface convergence line to the northeast of Grande Prairie with northwesterly winds on the southwest side and northeasterly winds on the northeast side (Figure 2). This surface convergence appears to have crossed the Grande Prairie area between 21Z and 22Z with the winds veering and pressure rising at Grande Prairie after the tornado occurrence.

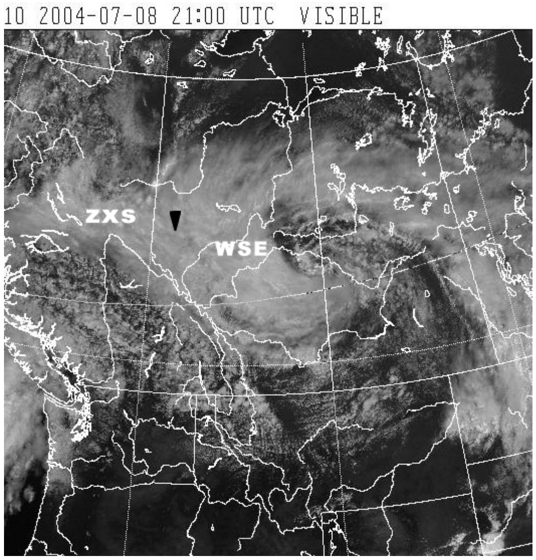

Figure 1. Visible satellite photo centered over eastern Alberta, Canada. The approximate locations of the Prince George (ZXS) and Stony Plain (WSE) upper air site are located just below their identifier. The location a Grande Prairie is near the top of the black triangle.

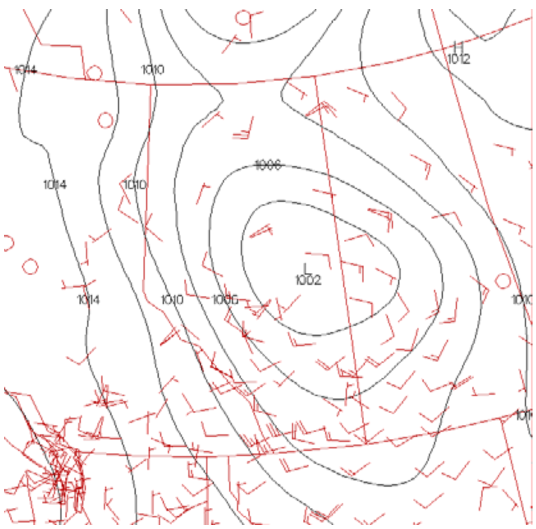

Figure 2. Surface wind field and objectively analyzed isobars at 21Z July 8, 2004. Image by Plymouth State University "Weather Center".

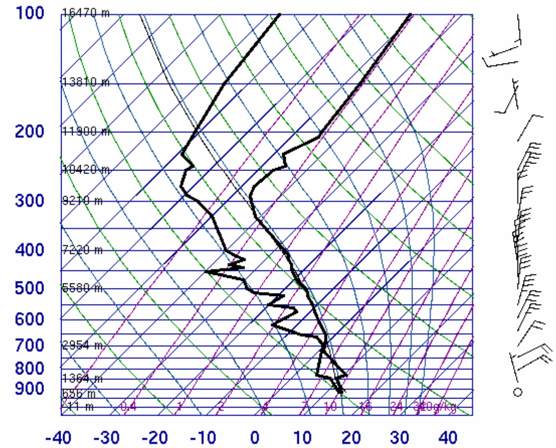

Figure 3. Sounding from Stony Plain (WSE) for 00Z July 9, 2004. Image by Plymouth State University "Weather Center".

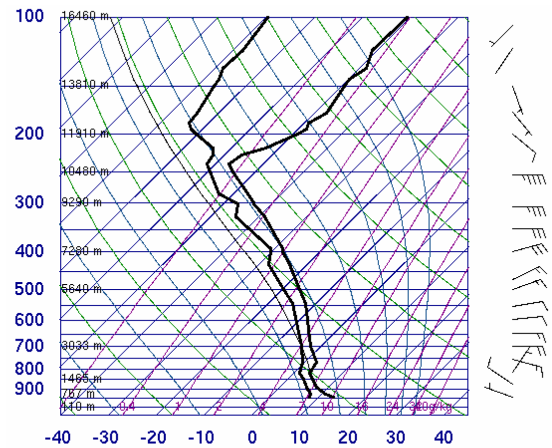

Figure 3. Sounding from Prince George (ZXS) for 00Z July 9, 2004. Image by Plymouth State University "Weather Center".

The surface temperature and dewpoint at the time of the tornado were 16C/13C respectively. GEM Model data combined with the observed surface data indicate that the CAPE in the area was less than 300 J/kg.

3. RADAR ASSESSMENT

Northwestern Alberta is monitored by the Spirit River Doppler radar. It is a 5-cm radar with a beam width of 1.6 degrees (uncommonly large for a Canadian radar). Canadian radars use a 24 tilt elevation scan strategy for conventional data, then four

Doppler scans at 0.3˚ (for long range), 0.5˚, 1.5˚, and 3.5˚. This entire process provides complete storm data every 10 minutes.

The large beam width can compromise the radar's ability to identify detailed storm information. However, the Grande Prairie storm tracked only 60-70 km from the radar site.

The tornadic cell formed within a line of relatively shallow convection. No lightning was associated with the Grande Prairie until just after the occurrence of the tornado.

On radar (Figure 5), the cell has the similar appearance to a supercell, but of a very small scale (~7-10 km along its primary axis). An apparent "hook" trails the storm on the north-east side. The velocity data (Figure 6) indicates rotation within the storm encompassing almost the entire physical structure of the cell. Most storms, including the Grande Prairie cell, had persistent rotation in excess of 1 hour.

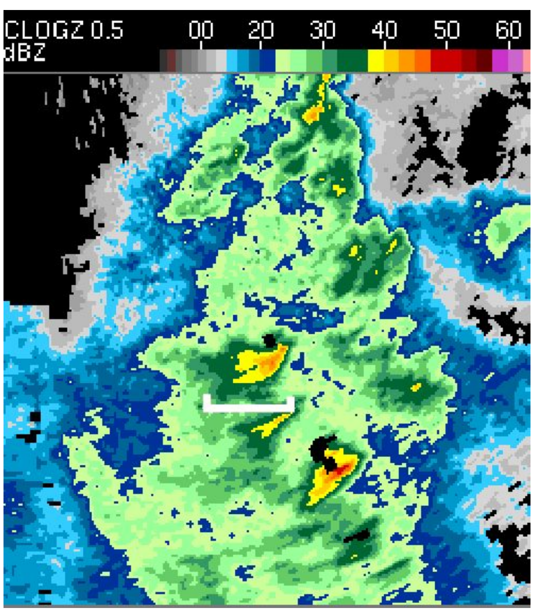

Figure 5. 0.5˚ Doppler-based PPI at 2120Z July 8, 2006. The Grande Prairie storm is in the center of the image. The white scale represents 10 km.

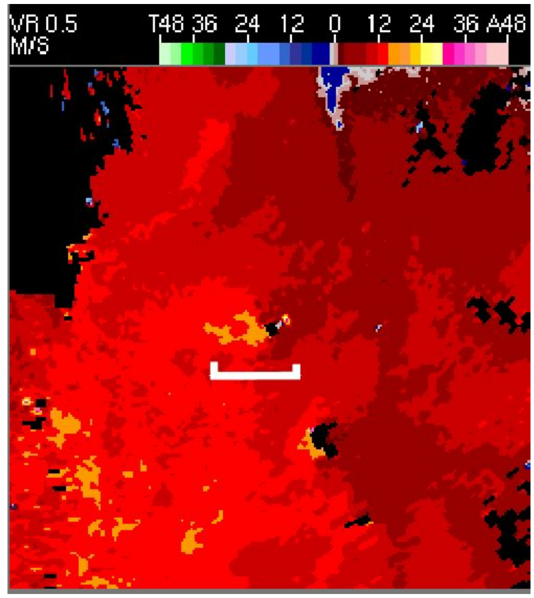

Figure 6. Radial velocity image from 0.5˚ PPI at 2120Z July 8, 2004. The Grande Prairie storm is in the center of the image. The white scale represents 10 km.

The vertical cross-section (Figure 7) of the cell at the time of the tornado shows a weak overhang and an echo top over the low-level inflow gradient. However, the cell was of too small a scale to allow detection of most storm structures. The echo top (using only 15 dBZ) at the time of the tornado was roughly 4 km.

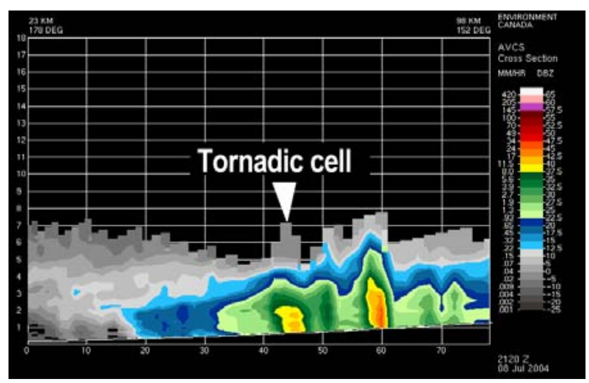

Figure 7. Vertical cross-section of tornadic cell at 2120Z July 8, 2004.

Most storms were indicating rotation during their lifetime. Cross-sections of larger storms (e.g. Figure 8) more readily revealed supercell-like structures.

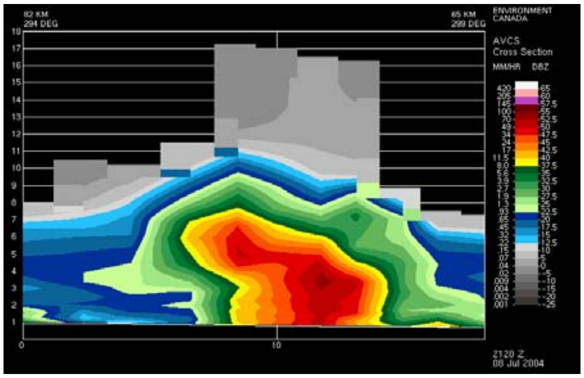

Figure 8. Vertical cross-section of larger supercell occurring at the same time as the Grande Prairie storm.

4. DISCUSSION

Traditional supercell-type thunderstorms have been well-defined in the past (e.g. Doswell et al, 1990). In recent years, smaller forms of the supercell, including tornadic examples, have been defined as "midget supercells" (Davies, 1991), "mini-supercells" (Davies, 1992), "low-topped supercells" (Burgess et al, 1995), and "shallow supercells" (McCaul. 1996). Some studies (e.g. Davies, 1993) have used the definitions to distinguish between supercell tornadoes and non-supercell tornadoes (e.g. Cooley, 1978; Wakimoto et al, 1989, Brady et al, 1989).

These small supercells have been identified beyond the Great Plains of the U.S, such as Japan (Suzuki et al, 2000), Australia (Hanstrum, et al, and California (Monteverdi, 1993). Canadian examples have also been noted (e.g. Vickers, 1990).

Much of the research (e.g. Wicker et al, 1996) into small supercells has noted that the absolute magnitude of the instability is not that important, but rather that there is an appropriate balance between storm depth instability and windshear.

According to Davies (2002a and b) tornadic environments with weak shear had the following in common: a well-defined pre-existing surface convergence boundary, sizable convective available potential energy in low-levels (CAPE below 3km) and motion that keeps storm motion on or near the boundary with deviation to the right of the mean wind. Also, Davies (2002, with his personal communications with Matthew Bunkers) indicated that a surface-based 0-3 km CAPE of 200 J/kg, over the central plains, is quite large and occurs relatively infrequently.

The Grande Prairie storm appeared to form is similar conditions. There was likely a veering profile with primary instability confined to the lower levels.

This tornadic storm was barely a thunderstorm, with maximum tops, at the time, only near 4 km. In fact no lightning was detected from this cell until after the event. The nomenclature for used is arguably misleading. A "supercell" suggests something large and exceptional. Researchers and forecasters have added words like "mini", "low-topped", etc. to refine the spectrum of these events. However, these refinements somewhat diminish the storm's apparent threat.

Key structures used to identify supercells may no longer be detectable for such small storms. One may wonder whether the increasingly small scale of supercells is blurring the difference between these and the non-supercell tornadic storms. Fundamentally, as long as there is a balance between shear and instability, rotation and tornadoes are possible.

Finally, most of the studies referenced here have focused on the tornado aspect of mini-supercells. It is possible that the small scale prevents notable hail, flooding rains, and powerful winds. However, generally low bases and persistent rotation typical of "mini-supercells" may mean that the primary threat is tornadoes. Unfortunately, for that insight, most cells in the Grande Prairie case tracked through unpopulated areas.

5. REFERENCES

Brady, R.H., and E.J. Szoke, 1989: A case study of nonmesocyclone tornado development in northeast Colorado: similarities to waterspout formation. *Mon. Wea. Rev.,* **117**, 843-856.

Burgess, D.W., R. R. Lee, S. S. Parker, and D. L. Floyd, 1995: A study of mini supercells observed by WSR-88D radars. *Preprints*, 27th Conf. on Radar Met., Amer. Meteor. Soc, 4-6.

Colley, J.R., 1978: Cold air funnel clouds. *Mon. Wea. Rev.*, **106**, 1368-1372.

Davies, J., 1992: April 28, 1991: Another case of tornado-producing mini-supercells, *Storm Track*, January 1993.

__________, 1993: Small tornadic supercells in the Central Plains. *Preprints,* 17th Conf. on Severe Local Storms, Amer. Meteor. Soc, 305-309.

__________, 2002a: Significant tornadoes in environments with relatively weak shear, *Preprints,* 21st Conf. Severe Local Storms*,* San Antonio, TX, Amer. Meteor. Soc., 651-654.

__________, 2002b: On low-level thermodynamic parameters associated with tornadic and non-tornadic supercells. *Preprints*, 21st Conf. Severe Local Storms*,* San Antonio, TX, Amer. Meteor. Soc., 603-606.

Doswell, C.A. III, 1900: Moller, R. Pryzbylinski, 1990: A unified set of conceptual models for variations on the supercell theme. *Preprints*, 17th Conf. on Severe Local Storms, Amer. Meteor. Soc., 40-45.

Hanstrum, B.N., G.A. Mills, A. Watson, 1998: Cool-season tornadoes in Australia, part 1: synoptic climatology. *Preprints*, 19th Conf. on Severe Local Storms, Amer. Meteor. Soc., 97-100.

Kennedy, P. C., N. E. Westcott and R. W. Scott: Single-Doppler Radar Observations of a Mini-Supercell Tornadic Thunderstorm, *Mon. Wea. Rev.,* **121**, 1860-1870.

Kennedy, P. C., N. E. Westcott, and R. W. Scott, 1995: Reply, *Mon. Wea. Rev.,* **123**, 235-238.

Markowski, Paul M., and J. M. Straka, 2000: Picture of the month. Some observations of rotating updrafts in a low-buoyancy, highly sheared environment. *Mon. Wea. Rev.,* **128**, 449-461.

McDonald, M., 2005: *2005 Severe Weather Report.* Environment Canada.

Pietrycha, A. E., J. M. Davies, M. Ratzer, and P. Merzlock: Tornadoes in a deceptively small CAPE environment: The 4/20/04 outbreak in Illinois and Indiana. *Preprints* CD, 22nd Conf. on Severe Local Storms, Amer. Meteor. Soc., paper P1.3.

Suzuki, Osamu, H. Niino, H. Ohno, and H. Nirasawa, 2000: Tornado-producing mini supercells associated with Typhoon 9019. *Mon. Wea. Rev.*, **128**, 1868 – 1882.

Trapp, R. J., S. A. Tessendorf, E. Savageau Godfrey, and H. E. Brooks: Tornadoes from squall lines and bow echoes. Part 1: Climatological distribution, *Wea. Forecasting*, **20**, 23-34.

Vickers, G.G., 1990: Two Small Alberta Tornadoes. *Preprints*, 16th Conf. on Severe Local Storms, 522-525

Wakimoto, R.M., J.W. Wilson, 1989: Non-supercell tornadoes. *Mon. Wea. Rev.*, **117**, 1113-1140.

Wicker, L. J., and L. Cantrell, 1996: The role of vertical buoyancy distributions in miniature supercells. *Preprints*, 18th Severe Local Storms, Amer. Meteor. Soc., 225-229.