P3.55 A SATELLITE PERSPECTIVE OF THE PINE LAKE, ALBERTA TORNADO EVENT

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1. INTRODUCTION

Canada ranks second in the world for the number of tornadoes (behind the United States), with an average of about 80 per year (Newark, 1984). A significant number of these tornadoes often occur in the Prairies of western Canada (Alberta, Saskatchewan, and Manitoba).

A tornado occurred in the vicinity of Pine Lake in south-central Alberta (25 km southeast of Red Deer, CYQF, Fig. 1), from 00:45 to 01:15 UTC on 15 July 2000 (6:45 to 7:15 PM local time on 14 July). Twelve fatalities and 140 injuries resulted when the tornado moved across the Green Acres lakeside campground on the western shore of Pine Lake (producing F3 damage). This was the first fatal tornado event in Canada since the 31 July 1987 Edmonton, Alberta tornado. In addition to the tornado, this storm also produced golfball to baseball size hail. A chronology of the Pine Lake tornado event is available from Environment Canada (2000).

2. SYNOPTIC OVERVIEW

McCarthy (2001) describes synoptic conditions of the day in detail. A shortwave trough was moving eastward across British Columbia, producing a broad southwesterly flow across Alberta. The approach of a 50 ms^{-1} mid-upper level jet streak was enhancing deep layer wind shear over the region. Convection initially formed between 19:00 and 20:00 UTC over the foothills of the Rocky Mountains across southern and central Alberta, eventually moving northeastward across the plains. Surface observations showed evidence of a dryline across southwestern Alberta, but also suggested that a region of higher moisture existed east of the developing convection. A dewpoint of 61 F (16.1 C) was observed just ahead of the storm at Red Deer (CYQF) at 23:00 UTC, while farther to the east, the dewpoint at Coronation (CWCT) increased from 41 F (5 C) to 55 F (12.8 C) between 23:00 UTC and 00:00 UTC.

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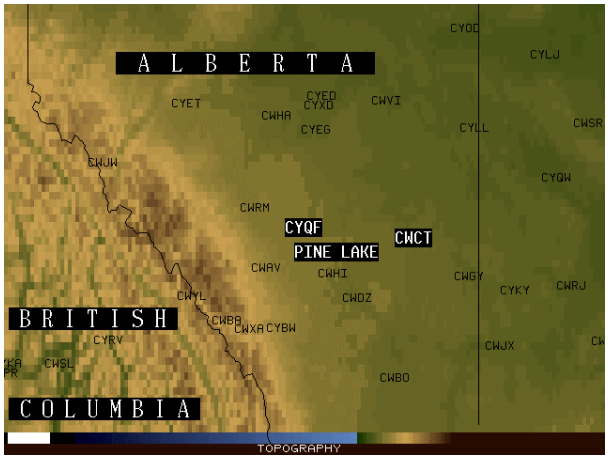

Fig. 1. Topographic map of southern Alberta and the surrounding region, showing station identifiers and the location of Pine Lake.

3. SATELLITE OBSERVATIONS

The two operational National Oceanic and Atmospheric Administration (NOAA) Geostationary Operational Environmental Satellite (GOES) were the eastern GOES-8 (centered at 75 W longitude) and the western GOES-10 (centered at 130 W longitude). Rapid Scan Operations (RSO) were activated for both GOES-8 and GOES-10 during the afternoon of 14 July, due to the potential for severe convection over the eastern US and also over Montana. During RSO periods, GOES imagery is available at 5-10 minute intervals (instead of the standard 15 minute interval imagery). In addition, GOES-11 (centered at 104 W longitude) had recently been launched, and was undergoing a Science Test where continuous RSO imagery was being generated during the July and August test period.

This event therefore provided a unique opportunity to view the development and life cycle of a high latitude tornadic supercell using multi-angle rapid-interval imagery from the 3 separate GOES platforms. A timely overpass of the NOAA-12 polar orbiting satellite also provided imagery of the developing convection prior to its producing damaging winds, large hail, and the Pine Lake tornado.

3.1 GOES-8 and GOES-10 imagery

Of the two operational GOES, the viewing geometry was most favorable from the western GOES-10 satellite. At 23:11 UTC, the GOES-10 10.7 micrometer InfraRed (IR) brightness temperature of the Pine Lake cell first became colder than -50 C, which was approximately the temperature of the tropopause (-51.5 C at 228 mb) on the 00:00 UTC 15 July Edmonton, Alberta rawinsonde report. A few images later (23:30 UTC, about 75 minutes prior to the Pine Lake tornado), an "Enhanced-V" cloud top signature became evident (Fig. 2), which often indicates convection that is producing or will soon produce damaging winds, large hail, or tornadoes (McCann, 1983).

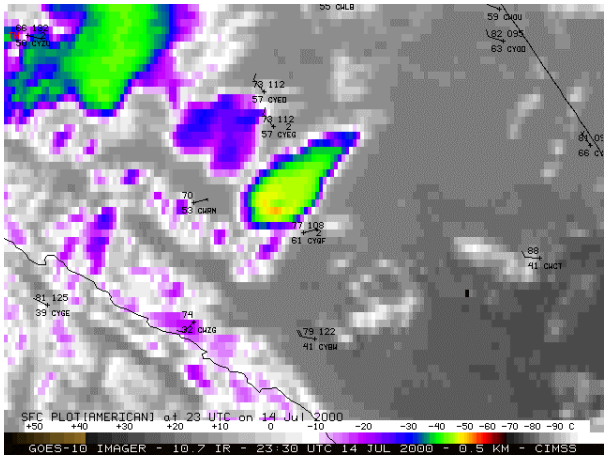

Fig. 2. GOES-10 10.7um IR image at 23:30 UTC, showing the initial "Enhanced-V" signature on the Pine Lake storm.

An animation of the GOES-10 visible imagery reveals that a small cloud element (a weak cell apparently unable to continue to organize and intensify) located just south and southeast of the Pine Lake storm appears to merge with the main cloud region around 23:30-23:40 UTC. Shortly after that time, the following is evident on the visible imagery:

-- a very large "shelf cloud" extends outward along the forward (eastern) edge of the Pine Lake cell.

-- the back edge of the storm becomes noticeably "brighter" on the visible imagery, indicating that the cell is becoming more "upright" leading to a greater degree of solar reflection off of the rear (western) edge of the storm. Subtle hints of shadowing from the "backsheared anvil" are also seen at this time.

The extreme viewing angle from the eastern GOES-8 satellite is less desirable, but an animation of that visible imagery also shows some interesting aspects of the Pine Lake storm:

-- the aforementioned "shelf cloud" along the leading edge is more obvious, since the view is not blocked by the overhanging anvil portion of the storm; the flanking line convection is well illuminated (Fig. 3).

-- the hazy region just to the rear of the cell after 00:15 UTC reveals that there was likely significant blowing dust produced by the strong rear flank downdraft to the south and southwest of Red Deer (CYQF).

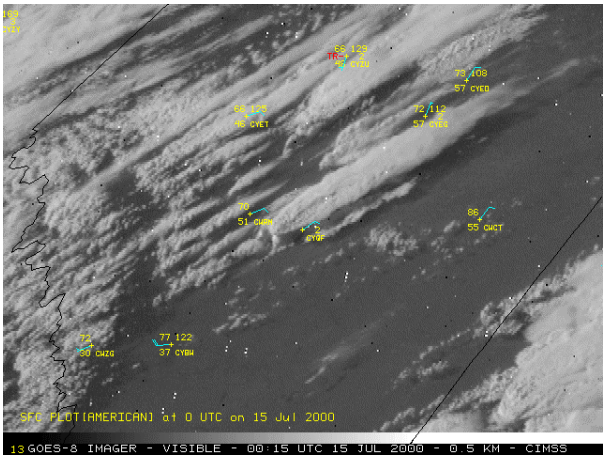

Fig. 3. GOES-8 visible image at 00:15 UTC, showing the shelf cloud along the leading edge of the storm, and flanking line convection along the southern edge.

Derived Product Imagery (DPI) from the GOES sounders are produced operationally on an hourly basis, and include total precipitable water (PW) and lifted index (LI). Unfortunately, the operational scan coverage of the GOES-10 Sounder only extended northward to about 50 North latitude, preventing the ability to monitor hourly stability or moisture parameters in the pre-convective environment across southern Alberta. The GOES-10 Sounder products did, however, hint that both an axis of instability and a moisture gradient extended from north-central Montana (where a severe thunderstorm watch had been issued at 23:30 UTC) northwestward into extreme southeastern Alberta and southwestern Saskatchewan (Fig. 4).

Total precipitable water derived from the High-resolution InfraRed Sounder (HIRS/3) on NOAA-15 (not shown) did indicate that a gradient of PW was in place across Alberta during the early afternoon overpass, with PW values around 1-7 mm in the west and 10-14 mm over eastern Alberta and western Saskatchewan.

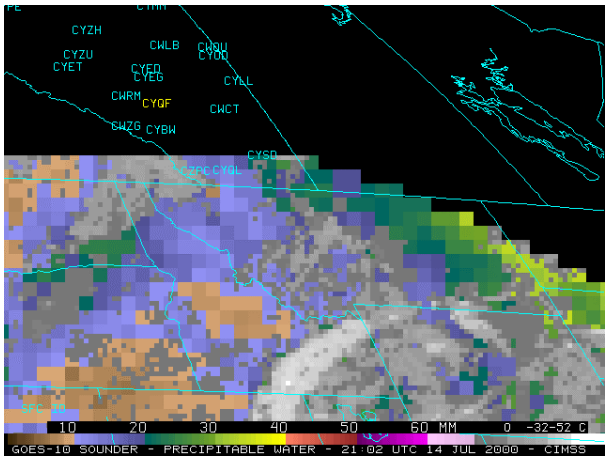

Fig. 4. GOES-10 sounder derived total precipitable water at 21:02 UTC.

3.2 NOAA-12 imagery

Visible and IR data from the 23:56 UTC overpass of the NOAA-12 polar orbiting satellite reveals finer detail in the cloud top and cloud top temperature structure (Fig 5), due to the higher resolution of the NOAA-12 AVHRR/2 instrument (1 km, versus the GOES IR resolution of 4 km). The NOAA-12 10.8 micrometer IR data also indicated colder cloud top temperatures within the "Enhanced-V" signature (-66 C, compared to -51 C measured by GOES-10 at 23:53 UTC).

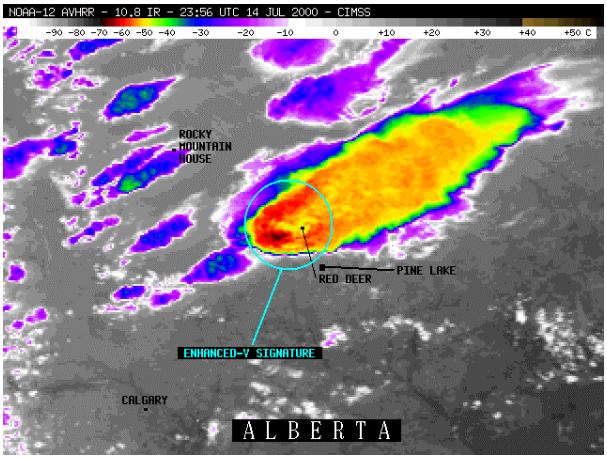

Fig. 5. NOAA-12 10.8um IR image at 23:56 UTC, showing the well-defined "Enhanced-V" signature.

3.3 GOES-11 imagery

The GOES-11 10.7-12.0 micrometer "split window" IR difference product (Fig. 6) shows evidence of a west-east oriented region of higher boundary layer moisture, along a Red Deer (CYQF) to Coronation (CWCT) line during the hours leading up to the development of the supercell that produced the Pine Lake tornado. This IR difference product highlights regions where the GOES-11 12.0 micrometer brightness temperatures are 5-6 K cooler than the corresponding GOES-11 10.7 micrometer brightness temperatures, due to attenuation by moisture pooled within the boundary layer (Chesters et al., 1983).

The Pine Lake supercell began to move to the right of the environmental (southwesterly) flow (Joe and Dudley, 2000), taking a more east-northeasterly path. The storms motion toward this region of increased boundary layer moisture may have played a role in the further intensification of the Pine Lake supercell prior to its producing large hail and the tornado.

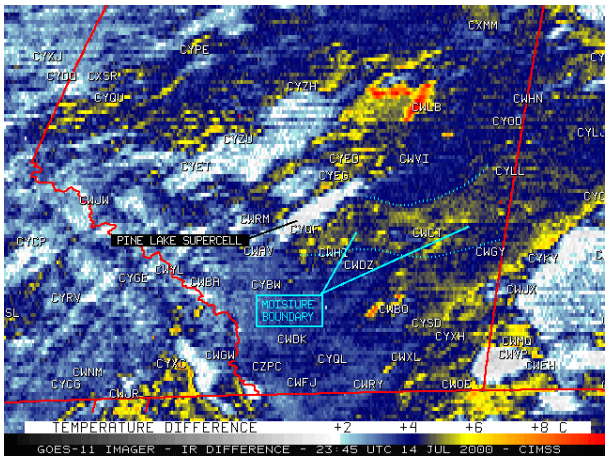

Fig. 6. GOES-11 split-window IR difference product at 23:45 UTC, showing the axis of higher boundary layer moisture in place to the east of the Pine Lake storm.

The Canadian National Radar Project site located at Carvel, Alberta (near Edmonton) collected radar data from the Pine Lake storm. Vertically Integrated Liquid (VIL) values increased dramatically (Joe, personal communication) around the time that the Pine Lake supercell encountered the axis of higher boundary layer moisture indicated by the GOES-11 split window IR difference product.

4. SUMMARY

The 14 July 2000 Pine Lake, Alberta tornado event was a unique opportunity to view a high latitude tornadic supercell using multi-angle rapid-interval imagery from 3 separate GOES platforms, as well as from NOAA polar orbiting satellites. Rapid Scan Operations imagery was available from GOES-8, GOES-10, and GOES-11, which showed several interesting aspects of the development and morphology of the convection across southern Alberta that day. In addition, a timely overpass of the NOAA-12 polar orbiter revealed striking detail in the Enhanced-V cloud top signature (20 minutes prior to the storm producing large hail, and 49 minutes prior to the Pine Lake tornado).

A west-east oriented axis of enhanced boundary layer moisture was evident across eastern Alberta using the GOES-11 split window IR temperature difference product. This feature was likely a key ingredient in the motion and intensification of the Pine Lake supercell.

Note: color versions of these GOES and NOAA satellite images (along with interactive Java animations) are available on the Cooperative Institute for Meteorological Satellite Studies (CIMSS) GOES Gallery at the following URL:

http://cimss.ssec.wisc.edu/goes/misc/000714.html.

5. REFERENCES

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McCann, D.W., 1983: The enhanced-V, a satellite observable severe storm signature. *Mon. Wea. Rev.*, **111**, 887-894.

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