TORNADIC EVENTS DURING UNSTABLE: USE OF SUPPLEMENTAL SOUNDINGS

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1. INTRODUCTION

Operational forecasters use upper air soundings in an attempt to characterize the atmospheric column at a specific point, however, crude extrapolation is sometimes necessary to apply this data to a larger scale, temporally and horizontally. Synoptic soundings available to operational forecasters in Canada are launched every 12 hours and coarsely-spaced, making convective evaluation difficult. Supplementary soundings have been found to be quite useful in filling in where the existing data network is course or in areas where surface characteristics, such as surface cover or terrain, are highly heterogeneous. Potvin et al. (2010) illustrated that proximity sounding are critical in accurately assessing the near and pre-storm thunderstorm environment. They demonstrated a range of 40-400 km and 30 minutes to 4 hours between the event and sounding was appropriate when attempting to measure the potential for thunderstorm and tornadic development.

The Alberta foothills are a favorable area to conduct thunderstorm research since they are an area of frequent convective (lightning) activity as shown in Figure 1.1**.**

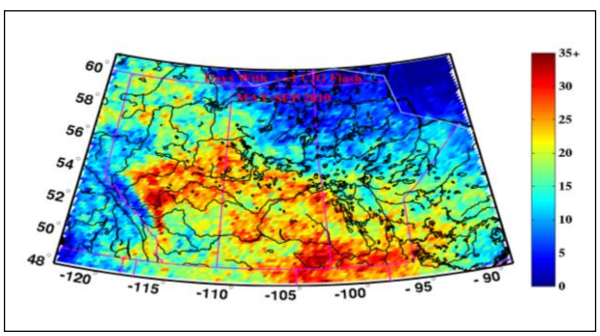

Figure 1.1: *1999 to 2009 Flash Density map (Taylor et al., 2011) ©American Meteorological Society. Used with permission.*

It is an area of highly variable terrain, as seen in Figure 1.2.

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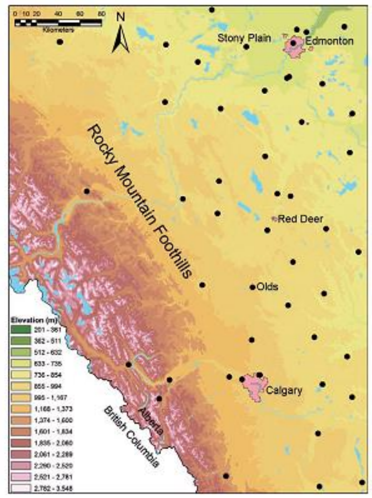


Figure 1.2: *Relief map showing the Edmonton– Calgary corridor. The foothills region is characterized by the transition from lower- lying agricultural areas (east) to the Rocky Mountains (west). Only one real-time upper air observation site, at Stony Plain, is available over the Alberta foothills. From Taylor et al., (2011) © American Meteorological Society. Used with permission.*

In the southeast, the badlands of the Cypress Hills are dry and contain little vegetation. The southern plains, which once use to be covered with tall grass, is now farmland. With the increase of population, there has been an increased land use for farming purposes. This has replaced the natural tall grass, with cereals, oilseeds, vegetables and pastures. Each different type of crop has a different effect on the surface land-atmosphere interaction. Each crop has a different root zone depth, which alters the potential amount of evapotranspiration (e.g. Hanesiak et al., 2004). Evapotranspiration provides low-level moisture to the dry Alberta atmosphere, increasing CAPE, to overcome any convective inhibition (CIN). Once August and September arrive, grain crops “head out” and evapotranspiration virtually ceases. In years of low soil moisture, this is reflected in lower hail and thunderstorm frequencies (Strong, 1997, Raddatz, 1998). Figure 1.3 indicates the domain of the Understanding Severe Thunderstorms and Alberta Boundary Layers Experiment (UNSTABLE) to be situated on a sharp transition zone from mixed grass and crop land to the mountains and subalpine. This surface variation may have a large control on the energy budget affecting heat and moisture partitioning of the boundary layer (Hanesiak et al., 2004; Pielke, 2001; Raddatz, 2007).

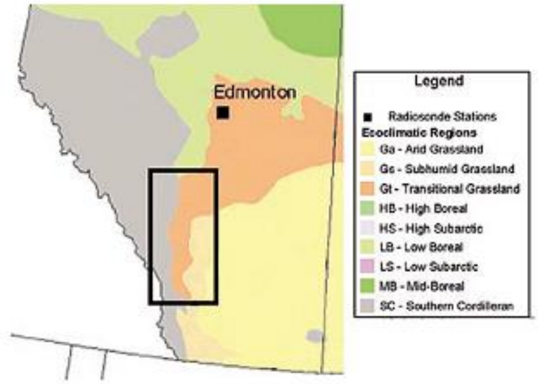


Figure 1.3: *Ecoclimate zones of Alberta (Taylor et al., 2008) indicating the surface types of Alberta. ©American Meteorological Society. Used with permission*

2. OBJECTIVES

UNSTABLE was conducted in south central Alberta in July 2008 with the overall goal of better understanding convective initiation processes and severe storm environments. UNSTABLE had several specific research questions (see Taylor et al., 2011 for more information) and this work contributes to the overall UNSTABLE goals.

Upper air soundings have been used in previous research to study Alberta Thunderstorms, however, what makes this research unique is the number of soundings used (four) as well as the mobility of two of the stations. The goal of this research is to illustrate how targeted soundings can be useful for severe storm prediction.

Two tornadic case studies are presented for this purpose. The following sections will describe the meteorological features that lead to the formation of tornadoes. Specifically, focusing on the soundings that were launched on these days and their proximity to the events.

The datasets used are those collected during UNSTABLE 2008. Other meteorological data, such as satellite, radar, upper air and surface maps are used to augment the UNSTABLE data as required.

3. RESULTS: JULY 7, 2008; AN F0 TORNADO NEAR CALGARY

3.1. Overview: Synoptic Scale Surface and Upper Air Analysis

This day was characterized by an upper trough at 250 and 500 hPa with associated cold air that crossed Alberta from 1200 to 0000 UTC. A northwest 49 m s^{-1} jet at 250 hPa entered the region by 0000 UTC on July 8th. 700 hPa displayed a northwest flow with a moist axis in southeast Alberta by 1200 UTC. At the surface and 850 hPa there was a generally weak synoptic northwest pressure gradient and wind, however, an easterly wind persisted closer to the foothills. At 850 hPa a thermal ridge sat along the Rocky Mountains with associated surface baroclinic zone that developed throughout the day. The tornado on July 7th, 2008 was reported just east of Calgary, AB and it was rated F0. The UNSTABLE soundings launched on this day were 60-70 km away from the tornado. There were three soundings launched. The closest standard synoptic sounding in proximity to the event was out of Stony Plain (WSE), 324 km away from the event. The WMO soundings on this day were either 10 hours prior or 2 hours after the event. Sounding locations are shown in Figure 3.1.

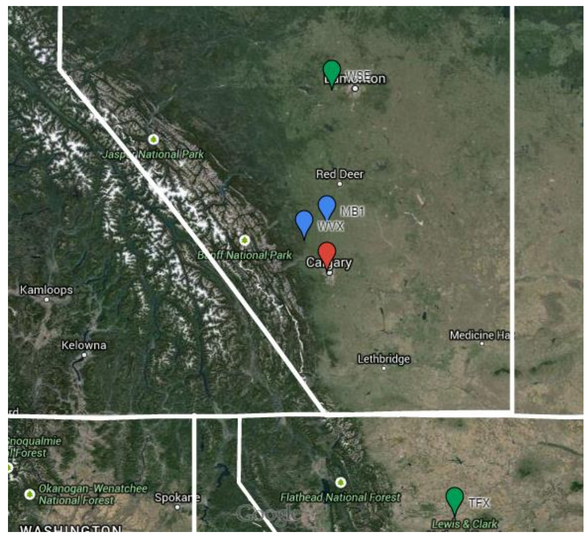


Figure 3.1: *Google Map from July 7th, 2008 of the standard synoptic sounding launch sites in green at Stony Plain, AB (WSE) and Great Falls, MT (TFX), UNSTABLE soundings in blue at MB1 and the location of the Calgary F0 tornado in red for reference.*

3.2. Boundary Layer Evolution

The dew point (Td) and mixing ratio (r) profiles, shown in Figure 3.2 displayed an increasing trend throughout the day below 775 hPa or about 1 km. This was reflected in equivalent potential temperature (θ_e) which displayed a 5 K increase below 800 hPa and about 2 K increase above 800 hPa, overall increasing instability in the column. Potential temperature (θ) also indicated a destabilization throughout the day. θ_e and θ are shown in Figure 3.3. A deeper moist layer was exhibited later in the day. The increase in moisture depth and magnitude may be due to advection and/or evapotranspiration. Temperature (T) was very similar between the two sites and three soundings, as seen in Figure 3.4. Both sites displayed weak inversions at different altitudes aloft. Surface wind direction was consistently out of the northeast between 90° and 30° for all soundings, indicative of surface moisture advection, and then sharply veered at 800 hPa to west northwest (300°). Winds near the surface in all soundings were weak; near 2.5 m s^{-1}. There was no evidence of a low-level wind maximum in the soundings from WVX (1558 and 1729 UTC), shown in Figure 3.5 but by 2238 UTC in the soundings launched from MB1, there seemed to be a mid-level wind maximum developing at 650 hPa of 15 m s^{-1}. The winds aloft in all soundings were also stronger than most days during UNSTABLE; 46 m s^{-1} at 250 hPa which weakened through the day to 36 m s^{-1}.

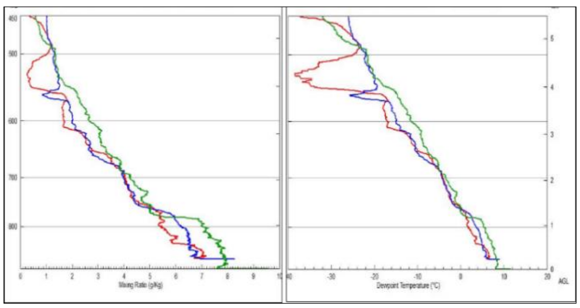


Figure 3.2: *Mixing ratio (right) and dew point temperature (right) profiles from WVX at 1558 (red), WVX 1729 UTC (blue) and MB1 at 2238 UTC (green) on July 7th 2008.*

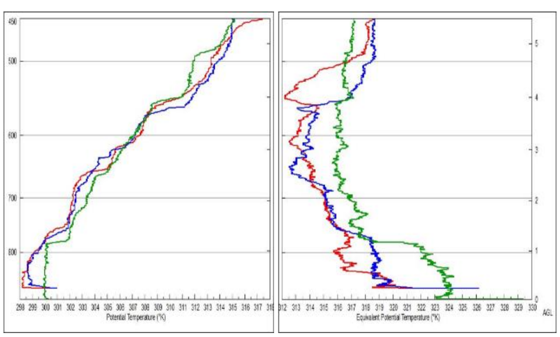


Figure 3.3: *θ (left) and θ_e (right) from WVX at 1558 UTC (red), WVX 1729 UTC (blue) and MB1 at 2238 UTC (green) profiles from July 7th, 2008.*

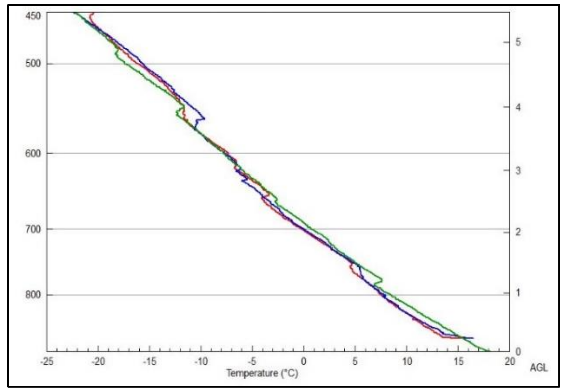


Figure 3.4: *Temperature profiles on July 7, 2008 from WVX at 1558 UTC (red), WVX at 1729 UTC (blue) and MB1 at 2238 UTC (green).*

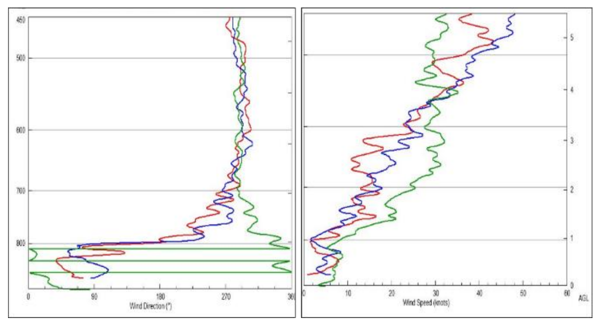
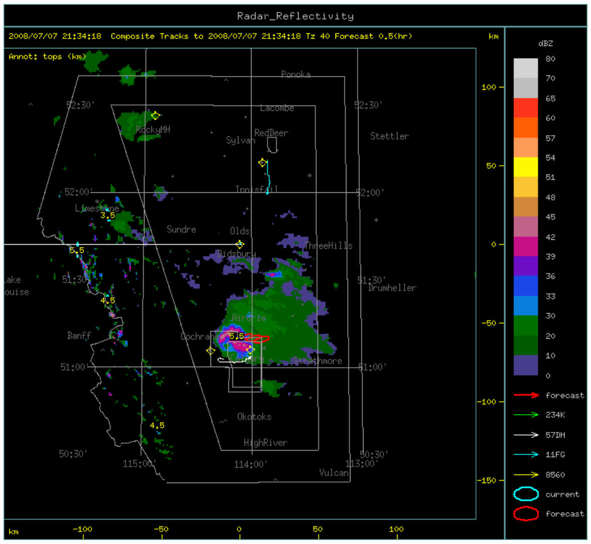


Figure 3.5: *Wind direction (left) and speed (right) profiles from WVX at 1558 UTC (red), WVX at 1729 UTC (blue) and MB1 at 2238 UTC (green) on July 7, 2008.*

3.3. Radar Chronology

At 1820 UTC the first 1.5 km CAPPI echo was observed on the Strathmore (XSM) radar and similar time on the Olds (WMI) radar. The first lightning strike was observed at 1910 UTC and a mesocyclone was identified on the XSM Doppler velocity at 1940 UTC. First radar reflectivities were identified at 7 km by 1950 UTC. The thunderstorm became more organized by 2030 UTC. On the WMI radar at this time it began exhibiting supercell characteristics such as a hook on the south end of the storm and a v-notch, as seen in Figure 3.6. As it tracked southeast passing over Calgary, AB (YYC) at 2150 UTC, the cell began to move to the right of the mean wind between 2140 and 2200 UTC. This then placed YYC in the hail and rain swath and the weak tornado just to the south. The hail was 20-30 mm in size with maximum reflectivities reaching 60 dBz at 7 km. Echo tops reached 10 km at 0010 UTC on the 8th before weakening into an area of showers near Strathmore and Brooks, AB.

a)



b)

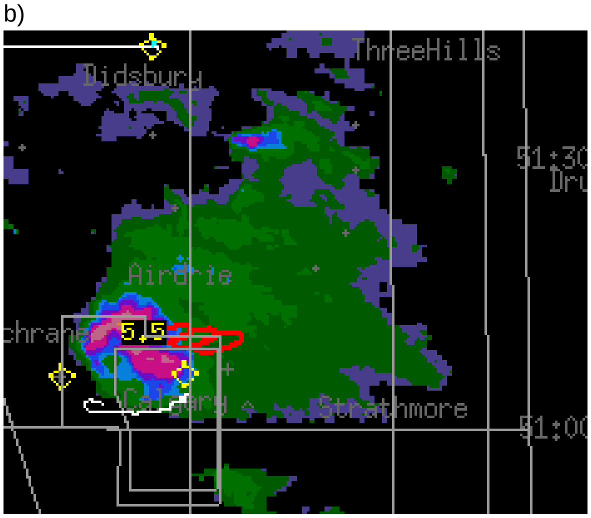


Figure 3.6: *WMI 1.5 km radar reflectivities at 2134 UTC on July 7, 2008. With a zoomed in image of the storm in b.*

3.4. Sounding Representativeness

The MB1 sounding at 2238 UTC in Figure 3.7 and associated hodograph in Figure 3.8 was 71 km away and 38 minutes after the tornado was reported. The MB1 sounding exhibited 1298 J kg^{-1} of surface based CAPE (SBCAPE), which is shaded in red. It is distributed evenly throughout the column indicating low-level upward vertical accelerations would not be significant, however, it was enough to sustain a long lived mesocyclone, which produced hail and a tornado. Low-level shear (0-2 km) was 7.17 10^{-3} s^{-1}. Surface winds were out of the east which is favorable for upslope advection of moist air, but the winds backed with height, producing associated small and negative low-level (0-1 and 0-2 km) SRH values, which are not favorable for tornadogenesis.

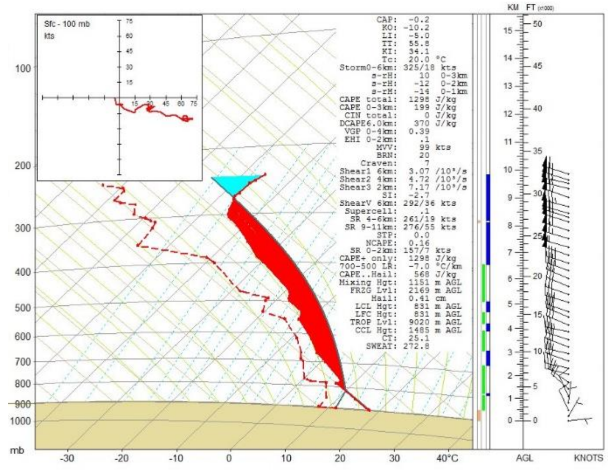


Figure 3.7: *MB1 tephigram at 2238 UTC on July 7, 2008.*

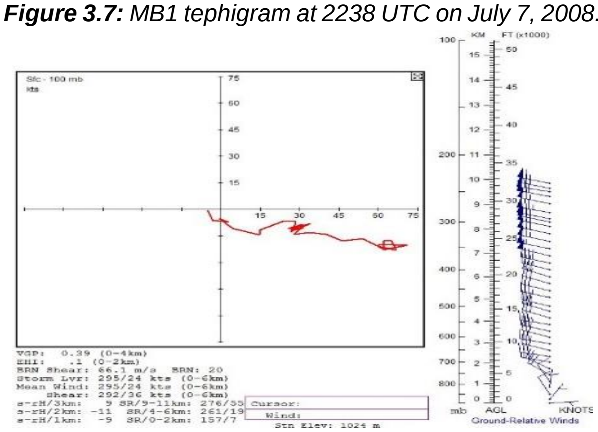


Figure 3.8: *MBI hodograph at 2238 UTC on July 7, 2008.*

Analyzing the 1729 UTC WVX sounding in Figure 3.9, which was 60 km away and 5.5 hours before the tornado indicated easterly winds in the bottom 1 km or 800 hPa veering to westerly by 1.5 km or 750 hPa. This is identified in the hodograph in Figure 3.10 with SRH values between 62 m^2 s^{-2} and 78 m^2 s^{-2} for 0-1 to 0-3 km respectively. The SBCAPE calculated from this sounding is less, 570 J kg^{-1} but this is due to the time (and possibly the location at which) it was launched since the surface had not yet reached maximum daytime heating to allow maximum potential SBCAPE. Low- level shear was less than what was observed at MB1, however, still significant enough for potential supercell maintenance at 5.95 10^{-3} $s^{-1.}$

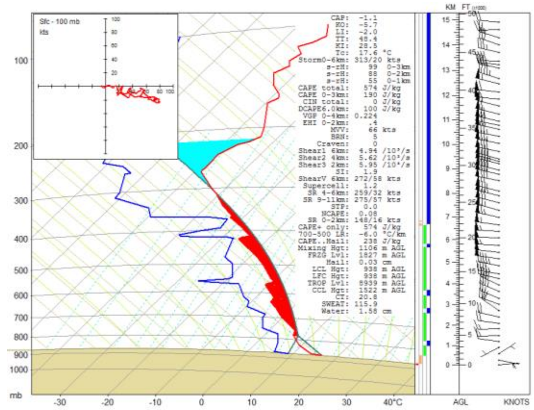


Figure 3.9: *WVX tephigram at 1729 UTC on July 7, 2008.*

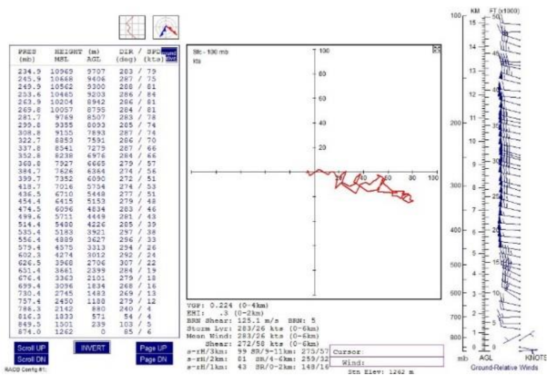


Figure 3.10: *WVX hodograph at 1729 UTC on July 7, 2008.*

In Figure 3.11, the WSE sounding exhibited northwest winds throughout the column. The air at the surface is also much drier; Td of 6 compared to 11°C in the MB1 sounding. This is because the WSE site is further north and east, further away from the foothills and into the northwest flow indicating cold and dry air advection. This produced the low SBCAPE values at WSE of 12 J kg^{-1} as well as a smaller 0-2 km shear (5.92 10^{-3} s^{-1}). However, it was the 0-6 km shear of 1.56 10^{-3} s^{-1} that was much less than what was seen in the UNSTABLE supplementary soundings (3.07 and 4.94 10^{-3} s^{-1} at MB1 and WVX respectively). LFC heights of about 800 m or just below 800 hPa were lower in the MB1 sounding compared to the LFC at WSE of 1984 m. The inversion present at 650 hPa in the WSE sounding is capping any free convection, however, the large amount of dry air present and pseudo-adiabatic lapse rate throughout much of the column are also not conducive to deep convection.

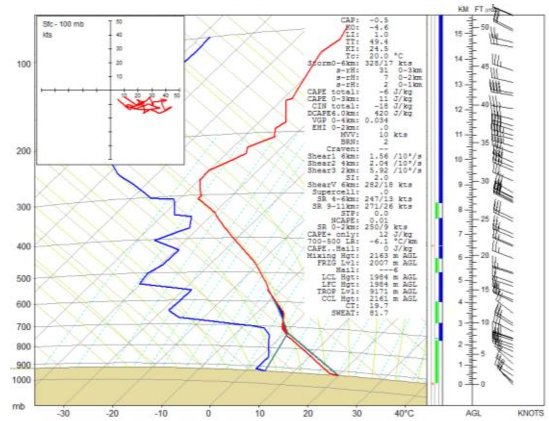


Figure 3.11: *WSE tephigram at 0000 UTC on July 8, 2008.*

4. RESULTS: JULY 15, 2008; AN F1 TORNADO NEAR VULCAN, AB

4.1. Overview: Synoptic Scale Surface and Upper Air Analysis

July 15th was initially not identified as a day that fulfilled the UNSTABLE criteria for an Intensive Observation Day (IOD). However, it turned out to be the most severe event in Alberta during the field campaign with golf ball size hail and an F1 tornado that followed a 100 m long and 30 m wide path through the southern periphery of the study area. Losses were estimated at $20,000 due to grain silos that were indented, torn from their foundations and thrown approximately 70 m.

At 1200 UTC, the 250 hPa level was characterized by west southwest flow with a jet core of 44 m s^{-1} tracking over the upper ridge into the southern Alberta region. It remained unchanged at 0000 UTC. At 500 hPa a similar upper ridge was present at 1200 UTC along with associated cyclonic vorticity and falling 1000 to 500 hPa thicknesses which advected into the region by 0000 UTC, ahead of the upper trough. At 700 hPa there was a zonal transitional flow as the ridge weakened and the trough tracked eastward. There was a weak flow at 850 hPa at 1200 UTC, however, by 0000 UTC on the 16th a weak low pressure center had developed on the baroclinic zone in the lee of the Rocky Mountains in the very southern section of the province. At the surface a weak ridge was present earlier in the day at 1800 UTC with a low over the foothills and an associated frontal system which tracked southeast to the Cypress Hills by 0000 UTC on the 16th.

The closest standard synoptic sounding in proximity to this region are launched from Stony Plain (WSE), just outside Edmonton, AB, Great Falls, MT (TFX) and Glasgow, MT (GGW). The distance of these soundings to the Vulcan tornado were 349, 351 and 537 km respectively and the launches occurred at 0000 UTC on the 16th, an hour after the tornado report, or 1200 UTC on the 15th, 11 hours before the event. The locations of these sounding locations are illustrated in Figure 4.1. The soundings that were launched as a part of the UNSTABLE project were out of Water Valley (WVX) at 1145 UTC, Didsbury, AB at 1203 UTC and Brant, AB at 2205 UTC. The distances from Vulcan, where the tornado was reported was 205, 202 and 31 km respectively. These sounding locations are also displayed in Figure 4.1. The distance of the Brant sounding to the Vulcan tornado, 31 km and being an hour before the event, was therefore at a distance in space and time that would allow for the measurement of quite accurate pre and near storm environment.

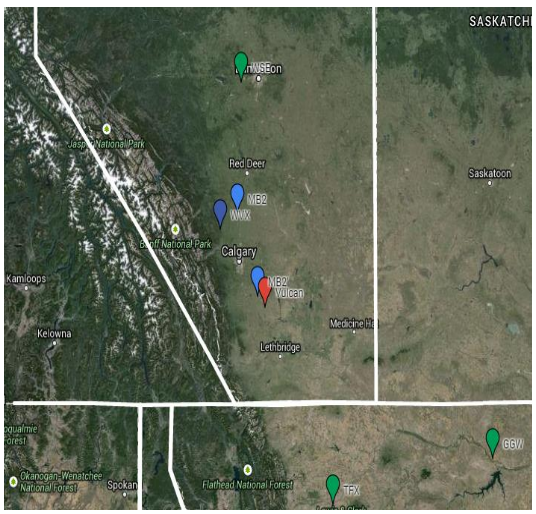


Figure 4.1: *Google Map of the UNSTABLE soundings in blue on July 15, 2008: MB2 at Didsbury, AB at 1203 UTC, WVX at Water Valley, AB at 1145 UTC, MB2' at Brant, AB at 2205 UTC, the standard synoptic soundings in green at Stony Plain, AB (WVX), Great Falls, MT (TFX) and Glasgow, MT (GGW) and the location of the Vulcan tornado in red for reference.*

4.2. Boundary Layer Evolution

There were three soundings on this day; two from MB2 and one from WVX. The one afternoon MB2' sounding only reached 700 hPa. There were two soundings in the morning, at 1145 UTC at WVX and 1203 UTC at MB2. WVX (1145 UTC) indicated the existence of a nocturnal temperature inversion at the surface, as shown in Figure 4.2, which was not evident in the MB2 (1203 UTC) sounding. T profiles warmed by 6°C at the surface throughout the day below 800 hPa from the 1203 to the 2205 UTC MB2 sounding. θe, in Figure 4.3, indicated a warm nose at WVX at 825 hPa. The MB2 sounding θe decreased by 3°K above 800 hPa as compared to the WVX sounding. However, the temperature in the 2205 UTC MB2 sounding increased in the afternoon above 800 hPa by 8 K. A shallow surface layer was about 2 K higher. Θ indicated instability increasing throughout the day comparing the morning and afternoon soundings, also in Figure 4.3

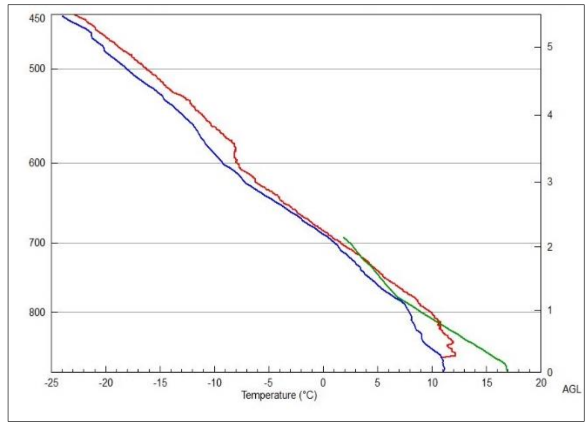


Figure 4.2: *Temperature profiles from WVX at 1145 (red), MB2 at 1203 (blue) and MB2 at 2205 UTC (green) on July 15, 2008.*

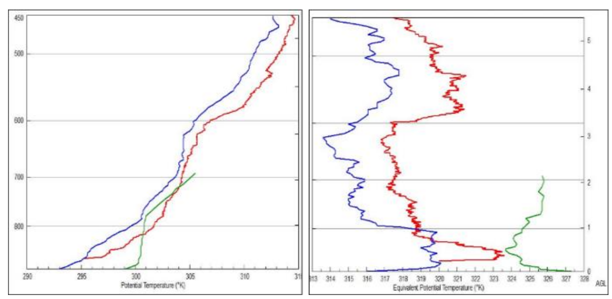


Figure 4.3: *θ (left) and θe (right) profiles from WVX at 1145 (red), MB2 at 1203 (blue) and MB2 at 2205 UTC (green) on July 15th, 2008.*

Td at the surface remained steady throughout the day, however, there was an increase in Td by about 8°C in the 2205 UTC sounding from 825 to 700 hPa. This was reflected in the r profiles as an increase in magnitude at 700 hPa; in the morning soundings, the r value was near 4 g kg^{-1} but by 2203 UTC it was near 6.2 g kg^{-1}. Near the surface the surface r also increased through the day from 7.5 to 9 g kg^{-1}. This is displayed in Figure 4.4.

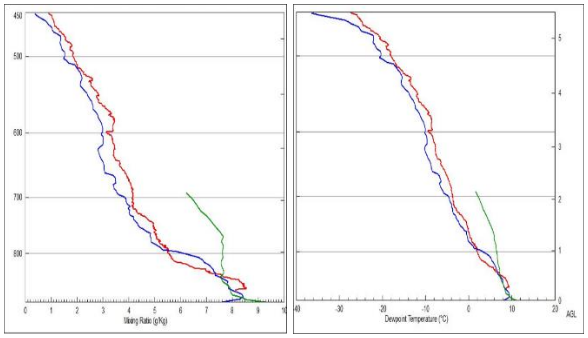


Figure 4.4: *Mixing ratio (left) and dew point (right) profiles from WVX at 1145 (red), MB2 at 1203 (blue) and MB2 at 2203 UTC (green) on July 15th, 2008.*

Surface winds backed throughout the day from southerly at 160° at 11:45 UTC to easterly at 100° at 2205 UTC. In this case this is indicative of an increase in streamwise vorticity and a higher likelihood of tornado development. This is discussed in more detail in section 4.4. There was an obvious low level wind speed maximum at 850 hPa which actually decreased in strength from 13 m s^{-1} to 10 m s^{-1} by 2203 UTC, however the vertical shear is more important than the magnitude of the wind speed. This is shown in Figure 4.5.

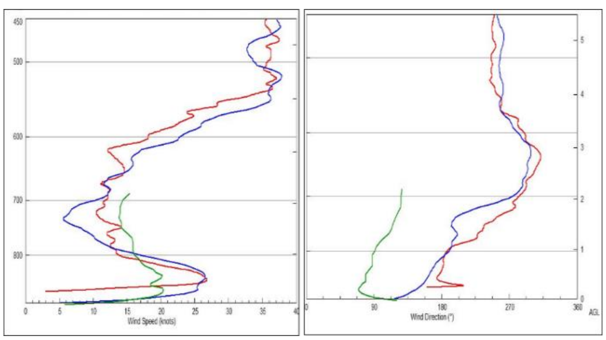


Figure 4.5: *Wind speed profiles from WVX at 1145 (red), MB2 at 1203 (blue) and MB2 at 2203 UTC (green) on July 15th, 2008.*

4.3. Radar Chronology

At the WMI radar an area of anomalous propagation (AP) was initially visible in the early morning. This is indicative of the capping inversion present which may have contributed to confining moisture and instability to the low levels to be explosively released later in the day. Weak elevated showers and embedded thunderstorms that tracked through the area in the morning added moisture to the low levels to be used later in the day as fuel for the surface based convection. Surface based convection initiated around 1730 UTC in a northwest to southeast line along the Rocky Mountain foothills. The surface based convection tracked in a southeast direction. Individual cells had reflectivities approaching 65 dBz at 1.5 km and 55 dBz at 7 km. As they tracked southeast and further developed, echo tops reached 10 km, vertical integrated liquid (VIL) was estimated as 20 kg m^{-2}, max hail (MESH) measuring 5.2 cm with percent of severe hail (POSH) up to 100%, and the height of the 40 dBz reflectivity was 8.5 km. The most severe cell that was identified as producing the tornado that caused F1 damage in Vulcan exhibited classic supercellular radar signatures, highlighting the possibility of a tornado. First, it was a classical "kidney" shape and had a weak hook on the western edge of the cell. On the Doppler velocity scans, a mesoscale velocity couplet was identified. Near the end of the day, after tracking southeast all day, it took a sudden right turn south. The radar reflectivity and Doppler images of the storm at its maximum intensity are shown in Figure 4.6 and Figure 4.7 below at 2300 UTC. An individual storm that propagates to the right of the mean wind can be indicative of a clockwise turning (veering) hodograph or wind shear profile which prefers the right flank for strong continuous updraft development (Monteverdi et al, 2003; Rotunno and Klemp, 1982; Weisman and Klemp, 1982).

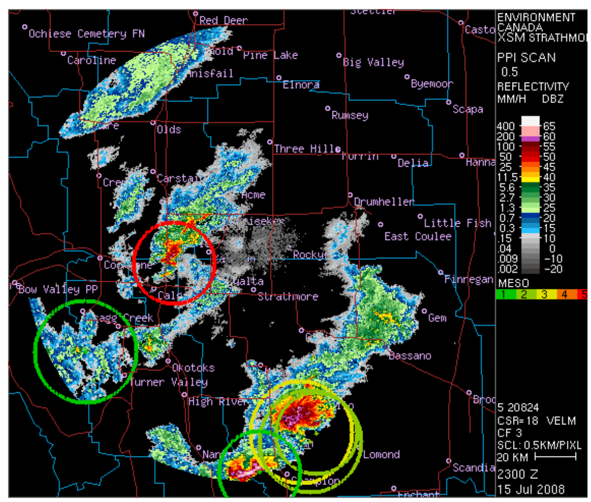


Figure 4.6: *2300 UTC 1.5 km radar reflectivity of the Vulcan tornado on July 15th, 2008.*

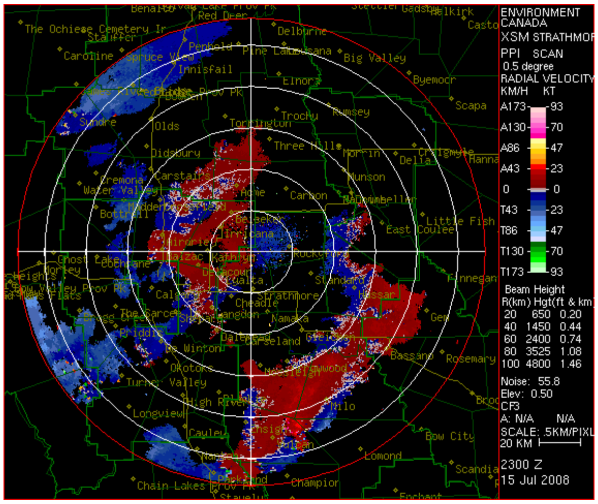


Figure 4.7: *2300 UTC Doppler velocity at 0.5° angle on July 15th, 2008.*

4.4. Sounding Representativeness

The synoptic sounding characteristics of note were in the 1200 UTC WSE sounding shown in Figure 4.8, exhibiting a westerly wind in the low-levels, however, by 0000 UTC as seen in Figure 4.9, a southeasterly wind at the surface had developed, which is more favorable for supercell development, given all other ingredients are present. Drier air in the mid-levels was displayed as well as a slight decrease in lifted indices which is further descriptive of a convectively unstable column, although an increase in showalter indices and a low CAPE value of 655 J kg^{-1} are not conducive to strong thunderstorm development as shown in the 0000 UTC sounding.

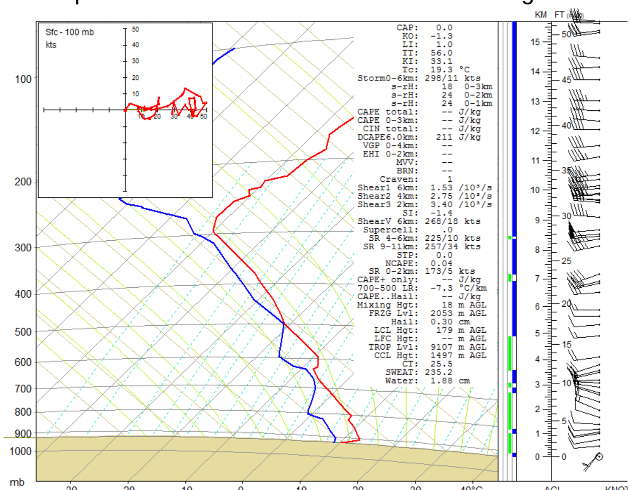


Figure 4.8: *1200 UTC WSE tephigram on July 15th, 2008.*

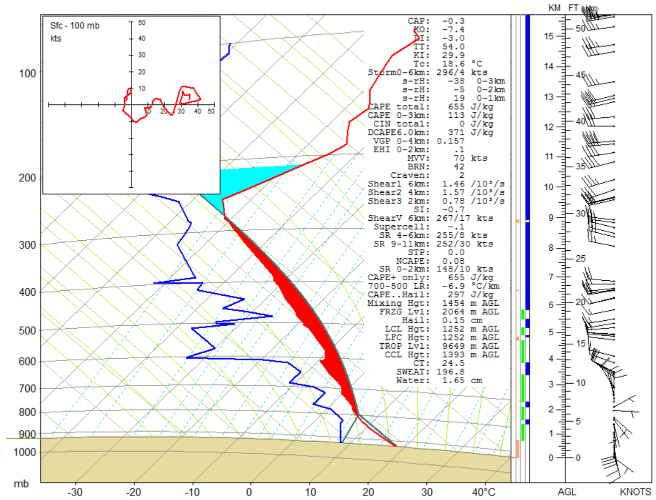


Figure 4.9: *0000 UTC WSE tephigram on July 16th, 2008.*

At TFX in Figure 4.10 and Figure 4.11, the low-level temperature profile became dry adiabatic in the afternoon. However, with the increasing depth of the convective boundary layer and subsident nature of the westerly wind, the low level moisture also decreased significantly. The winds were unidirectional throughout the column restricting low-level mesocyclone and therefore supercell tornado development.

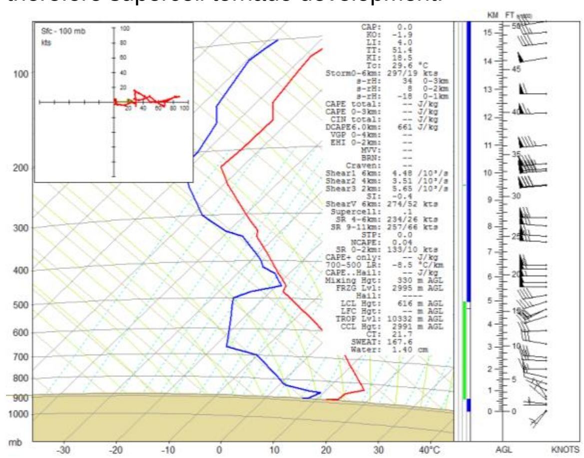


Figure 4.10: *1200 UTC TFX tephigram on July 15th, 2008.*

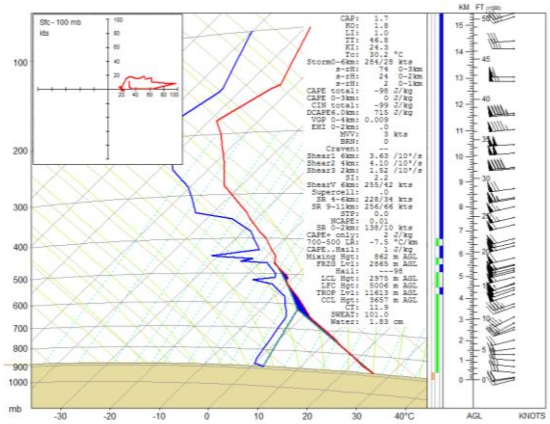


Figure 4.11: *0000 UTC TFX tephigram on July 16th, 2008.*

At GGW in Figure 4.12 and Figure 4.13, the low-levels similarly displayed increasing instability from the morning to the afternoon soundings, increasing the depth of the convective boundary layer while diluting the moisture through a deeper layer creating a dry layer at the surface more conducive to downburst winds than supercell and tornado development. The low-level winds did exhibit some veering with height from the south at the surface to west at 800 hPa.

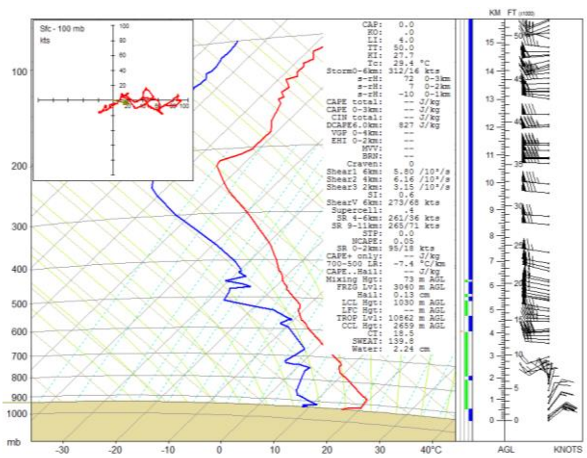


Figure 4.12: *1200 UTC GGW tephigram on July 15th, 2008.*

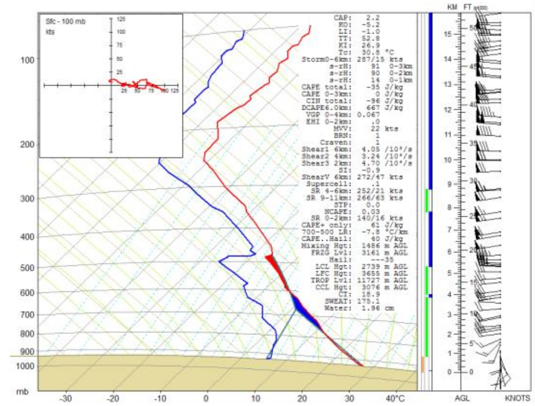


Figure 4.13: *0000 UTC GGW tephigram on July 16th, 2008.*

None of the standard operational synoptic radiosonde sites showed ingredients conducive for supercell storms or tornadoes. Since the only afternoon UNSTABLE sounding only reached 700 hPa, the morning UNSTABLE soundings from WVX and MB2 will be used, while modified at the surface with the temperature and dew point of the MB2' UNSTABLE afternoon sounding. Comparing the July 15, 2008 soundings from the UNSTABLE field data, the WVX sounding, in Figure 4.14, displayed slight low level veering in the winds. Modifying the surface temperature to the afternoon surface temperature and dew point revealed 1288 J Kg^{-1} of SBCAPE. Combined with 3.34 10^{-3} s^{-1}(39 kt) of 0-6 km shear (with 3.74 10^{-3} s^{-1} in the 0-2 km layer) indicating that the energy and wind shear conducive for long lasting, severe thunderstorms, and potentially supercells, were present. The 0-6 km shear is actually higher in some of the standard synoptic soundings, however, the low-level 0-2 km shear observed in the UNSTABLE soundings was in most cases higher than the standard soundings.

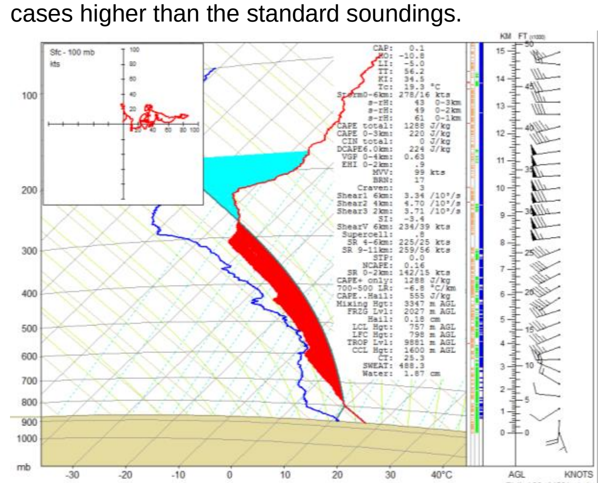


Figure 4.14: *WVX tephigram at 1145 UTC from July 15th, 2008 with surface temperature modified to the surface*

temperature and dew point reached in the MB2' afternoon sounding (17/11) mixed dry adiabatically with CAPE shaded in red

The MB2 1203 UTC sounding, in Figure 4.15 showed more favorable low-level winds with southeasterly at the surface veering to westerly by 700 hPa. This low-level southeasterly wind does not only indicate saturated, upslope lift, but since the storm motion, as indicated by the Bunkers method, was 303° (Figure 4.16), it also increases the streamwise nature of the vorticity, which is what results in a higher likelihood for supercells and tornadogenesis.

The CAPE was not possible to calculate in the 2205 UTC soundings since it terminated at 700 hPa, but when calculated in the modified 1203 UTC sounding by increasing the surface temperature to the tempeature and dew point reached in the MB2' sounding, in Figure 4.15, it showed higher CAPE values than what was calculated at all of the 0000 UTC standard synoptic sites; 1208 J kg^{-1}, compared to the 0000 UTC standard synoptic sites with maximum CAPE between the three sites of 655 J kg^{-1} at WSE. The standard synoptic sites also displayed drying of the low-levels. However, as shown in the 2205 UTC sounding, this moisture in the low levels was not diluted into a deeper layer due to the moisture advection occuring in this region. This was reflected as an increase in surface Td and the saturation of the mid levels between the 1203 and 2205 UTC soundings. This drying of the low-levels in the standard synoptic soundings would have had a significant impact on LFC, LCL and therefore, CAPE values.

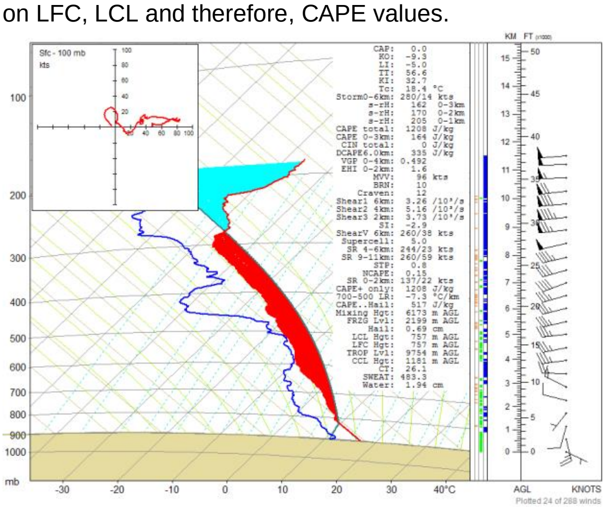


Figure 4.15: *Tephigram MB2 at 1203 UTC on July 15th, 2008 with modified surface temperature and dew point reached in the MB2' afternoon sounding (17/11) mixed dry adiabatically with SBCAPE shaded in red.*

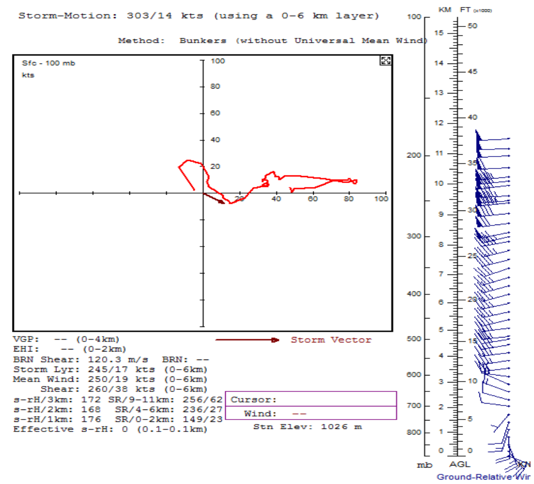


Figure 4.16: *Hodograph from MB2 at 1203 UTC on July 15th, 2008.*

The PW values remained similar between the UNSTABLE and standard sites. LIs were -4 and -5 in the modified morning soundings compared to -2 at the 0000 UTC standard sites. The surface Td was 11°C in the 2205 UTC MB2 sounding indicating moisture was not a limitation for storm development. TFX and GGW showed lower Td of 3 and 6°C respectively, although WSE showed a Td of 11°C as well, which is why WSE had the highest CAPE value of the standard soundings, with TFX having 2 and GGW having 64 J kg^{-1}. The BRN value in the WSE 0000 UTC sounding was 14 compared to 10 in the MB2 1203 modified with MB2' 2205 UTC sounding data. Any value less than 45 indicates a favorable ratio of CAPE to shear for supercell development (Thompson et al, 2003; Moncrieff and Green, 1972). However, WSE didn't have much CAPE, so this value would be not be representative.

5. CONCLUSIONS: JULY 7 AND JULY 15 2008 COMPARISON

The boundary layer (BL) in each case displayed differences and similarities. Surface T on the 15th did increase more through the day than the 7th, generating more SBCAPE for stronger updraft development. Td on the 15th increased significantly in the 700 to 825 hPa or 1.5 to 2 km layer; a difference of 4-7°C. This was reflected in the θe difference at 700 hPa of 10 K. The BL depth on the 15th seemed to be deeper than on the 7th when it was confined to below 850 hPa or about 1 km. All of these differences on the 15th can act to lower the LFC and LCL which is more favorable for tornadogenesis.

The wind regime on July 15th also indicated it was more favorable for tornadic development than the 7th. The 15th exhibited a low level wind maximum at 850 hPa of up to 13 m s^{-1} which on the 7th was less than 5 m s^{-1} all day. Higher low-level wind speed increased the low level SRH, leading to a higher potential for tornado development. This is evident in the hodographs as a larger low level cyclonic “looping”. A commonality between the days was they both displayed low-level easterly winds creating upslope lift of moist air.

The additional UNSTABLE soundings were useful in better representing the near storm environment. They captured the potential instability available for thunderstorm development by more accurately capturing the low-level moisture. More accurate low-level wind direction and SRH values were also observed. These features are crucial for the forecasting of tornadogenesis. Since this is an area lacking upper air observations, as well as it being an area where the mesoscale dynamics and surface terrain are complex and rapidly changing, more observations leading to better understanding are necessary.

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