P2.18 A PRELIMINARY ANALYSIS OF SEVERE QUASI-LINEAR MESOSCALE CONVECTIVE SYSTEMS CROSSING THE APPALACHIANS

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1. INTRODUCTION

It is well documented that Mesoscale Convective Systems (MCS) are capable of producing severe weather, including damaging winds, large hail, and tornadoes. A number of climatological studies have shown that particularly severe MCSs, specifically those defined as derechos (Johns and Hirt, 1987) are favored across the Upper Midwest and Ohio Valley into the central and southern Plains, but the frequency diminishes significantly east of the Appalachians (Evans and Doswell 2001; Coniglio and Stensrud 2004, Ashley et al. 2004, and others). Other research has examined the nature of the propagation of organized convective systems (not necessarily severe) across the U.S. (Carbone et al. 2002), including specifically the eastern U.S. and the Appalachians (Parker and Ahijevych 2007). These studies have noted both the unique diurnal tendencies in the east compared to the central U.S., as well as the tendency for redevelopment east of the Appalachian mountains of these kinds of systems. Still other findings (i.e., Doswell et al. 2005) revealed a relative minimum in severe convective wind reports (not confined to organized convection, however) in the Appalachians, with an increase immediately downstream over the Piedmont. A combination of factors likely contribute to this observation, including convection which either first initiates over the higher elevations of the Appalachians and then becomes severe as it moves east into a more unstable environment, or new convection that initiates east of the mountains. However, those severe quasi-linear MCSs approaching the Appalachians from the west, which initially weaken and strengthen again farther east, likely also contribute to this pattern of severe wind reports. The latter comprise the focus of this study.

Many of the above cited studies, as well as operational forecasting experience in the eastern U.S., suggest that the complex terrain of the central and southern Appalachians (with peak elevations of 1000-2000 m MSL) can influence the evolution of severe MCSs across this region, typically in a disruptive way. Complicating factors include: the potential modification of convectively-generated mesoscale cold pools by the terrain; lower surface-based instability compared to the lower elevations; downslope effects east of the mountains in westerly flow regimes; and damming of low-level cold/stable air east of the mountains in some situations. In fact, Frame and Markowski (2006) have examined the influence on linear convective systems by complex terrain using idealized mountain ridges in numerical simulations, including the blockage of shallow cold pools and enhanced lift immediately downstream.

The main objective of this preliminary stage of the study is to provide operational forecasters with an observationally-based analysis of favored environments for severe MCSs that cross the Appalachians and remain severe into the Piedmont regions. This will include a climatological analysis of favored times of year and day, as well as commonly observed synoptic patterns, and other contributing factors noted in the observations for several events that fell outside the more common trends.

Section 2 will define the domain and period of study, as well as the thresholds used to define upstream severe MCSs and further classify these events; section 3 will briefly describe these classification results; section 4 will provide a climatological analysis of all the events and identifies the favored times for

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severe crossing MCSs from those that do not cross; section 5 will examine the synoptic patterns with these events and the frequency to which they were observed; section 6 will examine a few noteworthy cases that were exceptions to the favored diurnal trends and will shed some additional light on important contributing factors; and sections 7 and 8 will offer some concluding statements and discussion of ideas requiring future work.

2. DATA AND METHODOLOGY

Primary data sources include archived severe report summaries, radar mosaics and other data sets on the Storm Prediction Center (SPC) severe thunderstorm events web page (www.spc.noaa.gov/exper/archive/events/index.html), which includes significant severe weather outbreaks starting with the year 2000. This database was used to first determine a candidate list of potential severe MCS events approaching the Appalachians from the west. This list was then narrowed down substantially after defining the specific criteria for an MCS, minimum number of severe reports associated with the MCS, and specific domain of study (described in section 2.1). A severe report-based definition was used to classify the events into several categories depending on the evolution. Archived severe reports were plotted using the PC-based application "SeverePlot" developed by the SPC (Hart 1993). Since the database for SeverePlot had not been updated to include 2006 data at the time the analysis was completed, the period of the study is from 2000-2005. Within this 6-year period, 52 separate severe MCS events were identified in the western portion of the domain that met the criteria (defined in section 2.2).

In comparing this study's results with many of the above cited papers, it is important to distinguish the major differences in the criteria and methodology used to define an event as well as the period of study (as discussed by Coniglio and Stensrud 2004). The criteria used in this study for upstream severe MCSs is not as stringent as the original derecho definition used by Johns and Hirt (1987), but it is also more limiting than the broader thresholds in some MCS studies since only those systems that produced widespread severe weather were considered.

2.1 Study domain

The entire domain for the study is shown in Figure 1. The north-south extent of the domain was limited to that portion of the Appalachians where the more abrupt terrain may have more impact on severe convection (based on some of the studies cited above as well as observational experience). This was arbitrarily determined to be approximately where the higher ridges extend above at least 1000 m MSL, which is roughly from extreme northern Georgia to southern Pennsylvania. This general domain was then divided into a northern section and southern section to orient the domain parallel to the mountain chain, and also to help distinguish those larger convective lines that might cross in one part of the domain but not in another. Interestingly, none of the events in the dataset exhibited this particular behavior, however several did move distinctly from northwest to southeast (sometimes turning in that direction from an original west-to-east movement as is commonly observed for long-lived MCSs). For these cases, the severe weather counts from both north and south sectors were combined. Next, the domain was divided into the following sections: a north and south mountain zone, labeled "NA" and "SA" for Northern Appalachian zone and Southern Appalachian zone respectively (different widths were defined for north vs. south due to the shape of the higher terrain), upstream zones (NW and SW) where a minimum number of initial severe reports were required for the event to be considered for the study, and finally zones east of the mountains (NE and SE) to determine if any severe weather reached east of the Blue Ridge (roughly the eastern-most edge of the NA and SA zones in Figure 1).

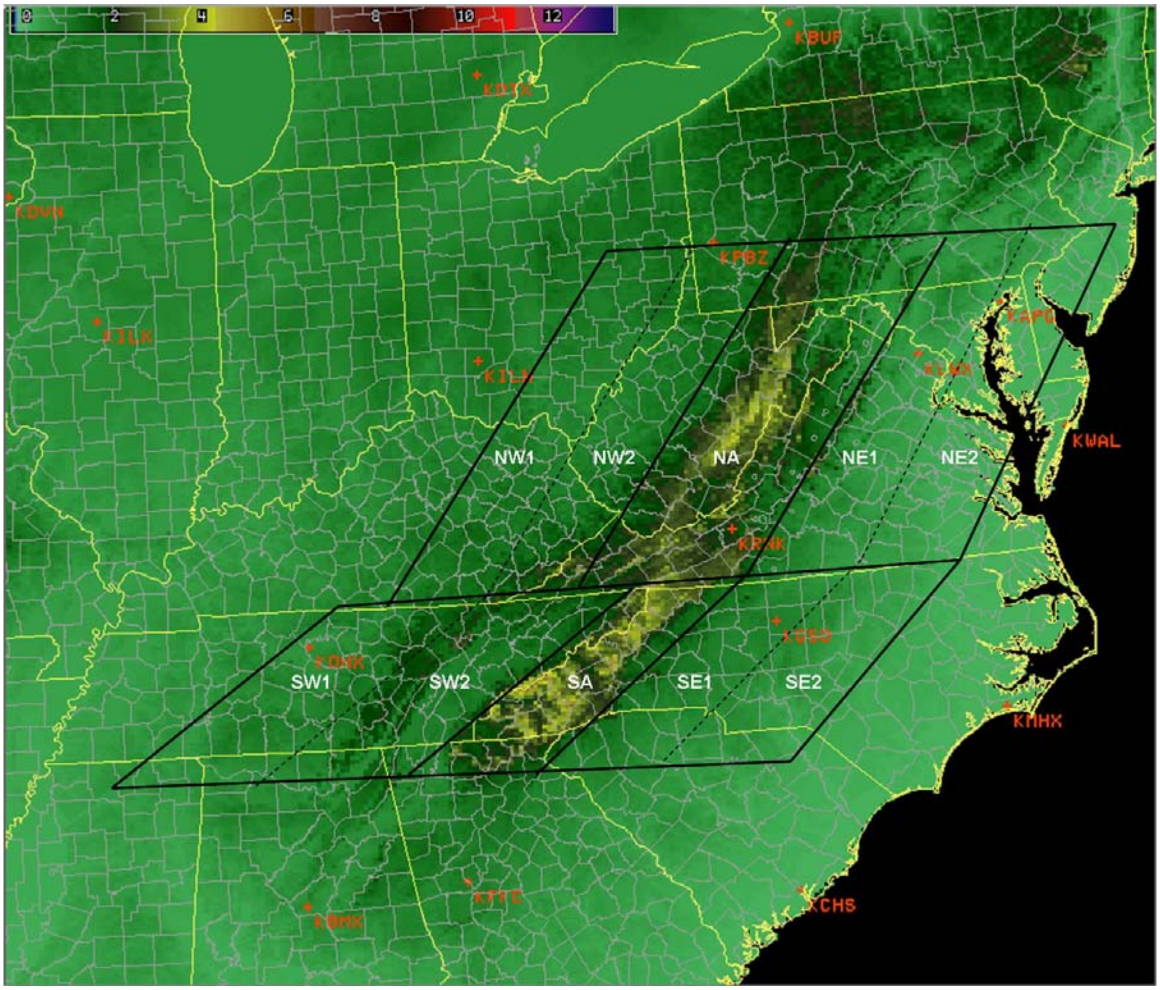


Figure 1. Domains used in the study, with “NA” and “SA” referring to Northern Appalachian section and Southern Appalachian section respectively. The scale for terrain height above MSL in the upper left is in thousands of feet, with dull yellow shades beginning roughly at 3000 ft (900 m), and bright yellow being close to 4000 ft (~1200 m). Upper air sounding locations are shown in red, with KRNK being the only one in a mountain sector.

The western zones were then further divided in order to help identify severe MCSs that weakened *before* reaching the western slopes, under the hypothesis that different decay mechanisms may be partly responsible between NW1 and NW2 (for example) compared to when the system moved into the mountains. The SW zones (SW1 and SW2) are farther west compared to the two NW zones, such that the western-most segment (SW1) is mainly west of the Cumberland Plateau in Tennessee. This was in case this relatively minor terrain feature tended to cause a disruption of the severe activity. The eastern zones were also divided into two segments each, in an attempt to identify any cases that did not cross but later redeveloped farther to the east.

2.2 Definitions

Since the objective of this study was to analyze severe MCSs approaching the Appalachians from the west and their subsequent behavior as they encounter the higher terrain, the initial requirement was to meet a radar-based definition of MCS, and then contain a minimum number of severe weather reports as it either moved into the far western portions of the domain, or in some cases developed within the western sub-domains. The radar definition used was consistent with that described in Coniglio et al.

(2007) for a “mature” quasi-linear MCS: 50 dBZ or higher echoes embedded within a nearly continuous line of 35+ dBZ echoes extending at least 100 km in length. The requirement used for MCS longevity based on this radar criteria was 2 hours or more.

Next, at least 10 reports of severe weather within the entire NW (or SW) zone directly associated with the MCS was required (any non MCS-associated reports were carefully omitted). This required plotting the severe reports in one or two hour windows and comparing closely with the radar loops. Fundamental categories for “crossing” and “not-crossing” the Appalachians, including some special sub-categories, are defined in Table 1.

CATEGORY	SUB-CATEGORY	DESCRIPTION
NOT CROSSING	Dissipating West	A significant reduction in number of reports (25%) between NW1 and NW2 (or SW1 and SW2), *and* only one or zero reports in the mountain zones (NA or SA). This sub-category of a “Not-Crossing” severe MCS is hypothesized to show a more nocturnal dissipation signal compared to the rest of the not-crossing events.
	Not-crossing	Smaller reduction in reports between NW1 and NW2 (or SW1 and SW2) compared to the Dissipating West sub-category (or an actual increase), and <8 reports in the NA zone (or <4 in SA since its size is considerably less than NA), and then *no reports* in the eastern zones (NE or SE). The Blue Ridge (the eastern edge of the NA and SA zones – see Fig. 1) was used as the defining line to fundamentally separate crossing from not crossing.
	Penetrating	The same initial criteria as the Not-crossing category, but allows for more reports in the mountain zones, as long as there are still *no reports* anywhere in the eastern zones. Considered a hybrid between crossing and not-crossing, but fundamentally still considered a not-crossing sub-category since no severe weather is observed east of the Blue Ridge.
CROSSING	Crossing	The same initial criteria for all the other categories, but with at least two reports in the mountain zones (NA or SA) and at least two reports in either of the eastern zones immediately adjacent to the mountain zones (NE1 or SE1). The lower threshold of required reports in the mountains compared to the west was chosen for two reasons: 1) the tendency for almost all systems to weaken somewhat as they move through the mountains, and 2) the overall lower population density. More than one report is required in the NE1 or SE1 zones to account for a stray report due to either an error in the SPC database or an accidental report counted from an isolated cell ahead of the MCS.
	Redeveloping	Same as the Not-crossing criteria but with two or more reports further east in NE2 or SE2, *or* the Dissipating West category with two or more reports anywhere in the east (NE or SE) and still associated with a radar-defined MCS; in other words a significant gap in space and time in severe reports in this case. This would be considered a special sub-category of the general crossing category.

Table 1. MCS categories, sub-categories and descriptions.

Due to the lower population density and inherent reduced severe report climatology across the mountains, the criteria for a crossing case did not utilize a consistently high number of reports across the entire domain from west to east, as might be required over a region of homogeneous terrain. The primary objective was to differentiate between those events that stop producing severe weather on the west side of the mountains (whether the radar echoes dissipate or not) vs. those that can still produce even a small amount of severe weather all the way across and into the Piedmont. Severe weather reports were also included if they were still occurring after the more intense echoes weakened and may no longer have technically fit the MCS radar definition, as long as the reports were clearly the result of the remnants of the mature MCS.

2.3 Further data analysis

After all 52 events were classified, archived synoptic maps were examined for all events from both the SPC significant event website as well as using images from the North America Regional Reanalysis (NARR) data (Kalnay et al. 1996), mainly from the Penn State University "e-Wall" website (http://www.meteo.psu.edu/~gadomski/NARR/). For each of the two fundamental categories, unique classifications for map types were subjectively determined, based primarily on 500 mb level data. Composites for these different map type classifications were created using the NOAA Earth System Research Laboratory interactive NARR composite web page – hourly option (http://www.cdc.noaa.gov/Composites/Hour/), which includes 3 hourly resolution data. For each event, the closest 3-hour analysis *before* the severe MCS first crossed into the mountains or dissipated, as determined from radar loops and severe weather report trends, was used to generate the composites. The time entering the mountains or dissipating was rounded to the closest hour for the purposes of creating a diurnal analysis of the fundamental crossing and not-crossing categories as well.

Finally, several anomalous events were identified which fell outside the more typically observed diurnal trends. Some of the environmental and radar data are examined more closely for these cases, including modified proximity soundings and the nature of the MCS as observed by radar (i.e., apparent strength of cold pool, or overall intensity and size). These observations were used to help further hypothesize some important controlling mechanisms which still need to be studied more thoroughly using additional data and hopefully numerical simulations.

3. CLASSIFICATION RESULTS

Based on the classification scheme described above, of the 52 total severe MCS events either entering the western domain or developing within it, 19 were found to fit the fundamental "Crossing" definition, producing severe weather across the Appalachian Mountains and into the Piedmont region. Of the 33 remaining fundamental "Not-crossing" events, eight were classified in the "Dissipating West" sub-category, while 12 were "Penetrating". These results are presented in Table 2. Even with the minimal report criteria used, crossing events constituted more than one third of all cases, which was somewhat higher than what anecdotal evidence suggested it would be.

CATEGORY	SUB-CATEGORY
NOT CROSSING (33)	Dissipating West (8)
	Not-crossing (13)
	Penetrating (12)
CROSSING (19)	Crossing (19)
	Redeveloping (0)

Table 2. MCS classification results (52 total cases)

This is also considerably higher than the 7-10% of convective systems that Parker and Ahijevych (2007) found for all organized convection in the eastern U.S., using a very similar domain. In fact, since many of the Penetrating events actually produced numerous severe weather reports well into the heart of the Appalachians (but still no reports east of the Blue Ridge), the number of Crossing and Penetrating combined is actually greater than the remainder of the Not-crossing cases, by about a 3:2 ratio. Also somewhat surprising, there were no cases that fit the definition for the Redeveloping sub-category. Additionally, there were no cases where the number of severe reports even increased between NE1 and NE2 (or SE1 and SE2). Re-intensification of radar reflectivities were observed in several cases as the MCS initially weakened to the west and then strengthened again to some degree east of the mountains. However in the six years studied, none of the cases intensified to severe thresholds within the defined domain. Most of the crossing cases did intensify immediately upon reaching the first eastern zone, but for some reason did not continue to produce severe reports into the NE2 or SE2 zones.

4. CLIMATOLOGICAL ANALYSIS

Figure 2 shows the seasonal climatology of the severe MCSs for this study, with the fundamental crossing vs. not-crossing categories distinguished by color. Clearly the peak of severe MCS activity just upstream of the Appalachians is during the warm season, with the greatest number occurring in May, then a relative minimum in June, followed by greater activity in July and August. Severe weather climatology for this part of the country does not support this minimum in June (Doswell et al. 2005), nor does the organized convective activity shown by Parker and Ahijevych (2007), however they do show a subtle minimum in June for particularly large systems,(> 250km). Ashley et al. (2004) also show a June minimum for derecho events in their 10 year study for the entire country, and suggest this may be due to a combination of serial and progressive derechos still occurring in late spring months, while later in the summer (July maximum) is dominated by progressive derechos in northwest flow. A similar explanation may be partially responsible for the June minimum shown in our severe MCS database, however the fact that the signal is so strong is more likely due to a relatively small sample size (52 events compared to 290 in Ashley et al. 2004). No severe MCSs were observed in the month of September, with a small secondary peak (only three cases) in November. Again, this is not consistent with the findings from Parker and Ahijevych (2007), but at least several of the cases in their study were from tropical systems which moved into the domain from an easterly or southerly direction. The distinction between crossing and not-crossing cases also shown in Figure 2 reveals that crossing cases are most common in May, July, and August, and in July and August are just as common as not-crossing cases.

An additional important observation is that a majority of the April and May cases occurred in the southern sections of the domain, while a majority of the July and August cases occurred in the northern sections (not shown). This is consistent with some of the derecho studies cited above, including Ashley et al. 2004.

Diurnal climatology of all events is shown in Figure 3, which includes a breakdown of the fundamental crossing and not-crossing categories. Time is shown on the x-axis in UTC, and for the study area there is a 4-5 hour subtraction to convert to local time during the warm season. The time plotted in Figure 3 for each event is the closest hour to when the severe MCS first reached the western slopes of the mountains. Clearly there is a strong signal for increasing frequency during the afternoon and evening hours, which quickly diminishes after about midnight local time. Very few events (and no crossing events) occur overnight or in the morning hours. This is very consistent with diurnal climatology for MCS activity in the eastern U.S. as shown in a number of studies, including Carbone et al. (2002) and Parker and Ahijevych (2007). Another strong signal is that the midday to late afternoon hours between 15 - 21 UTC are dominated by crossing cases by a 13:1 ratio, while all other times are dominated by not-crossing. This strongly suggests that daytime heating is a very significant factor in determining whether severe MCSs can survive through the mountains. No severe MCS managed to continue across the Blue Ridge if the severe MCS reached the western slopes of the Appalachians between 06 and 14 UTC during this six year study.

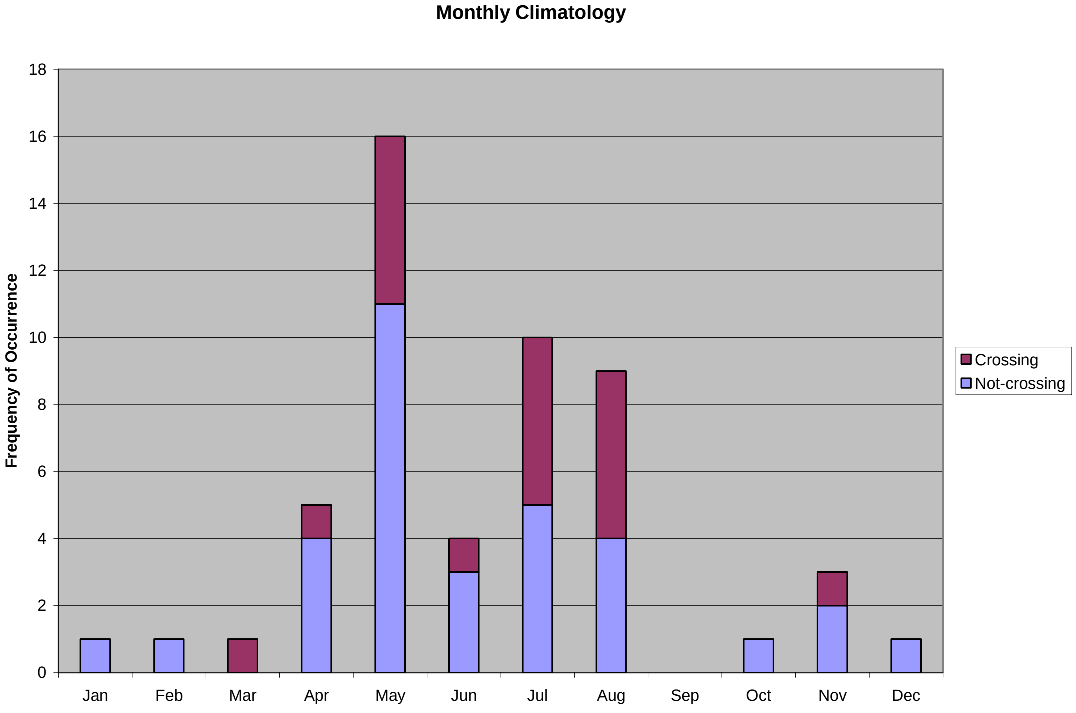


Figure 2. Annual climatology of severe MCSs in the study area, with the number of cases shown on y-axis. Crossing cases are shown in purple, and not-crossing are in blue.

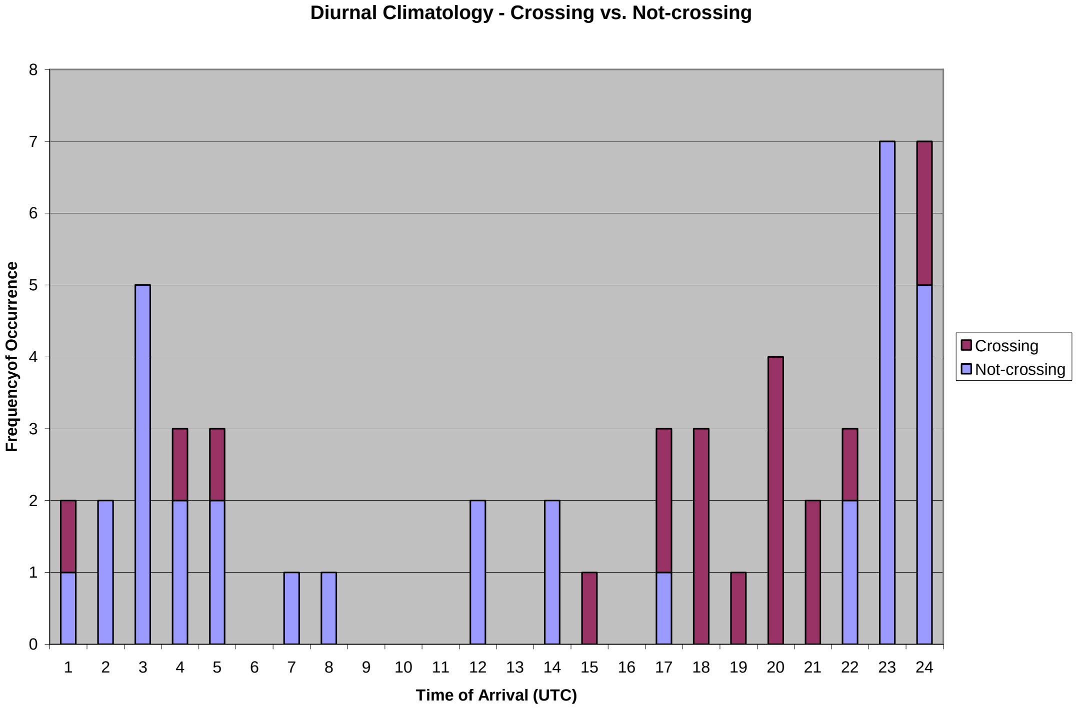


Figure 3. Number of severe MCSs reaching the western slopes of the Appalachians or dissipating to the west during each hour (UTC). Crossing cases are shown in purple, and not-crossing cases are in blue.

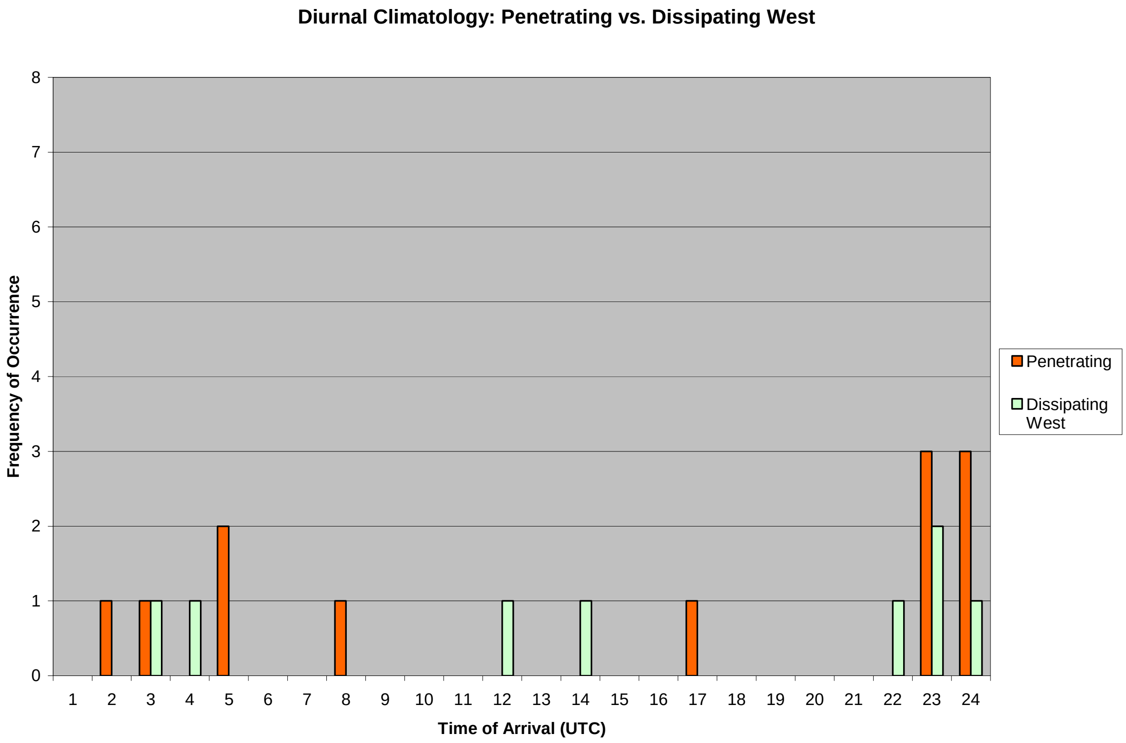


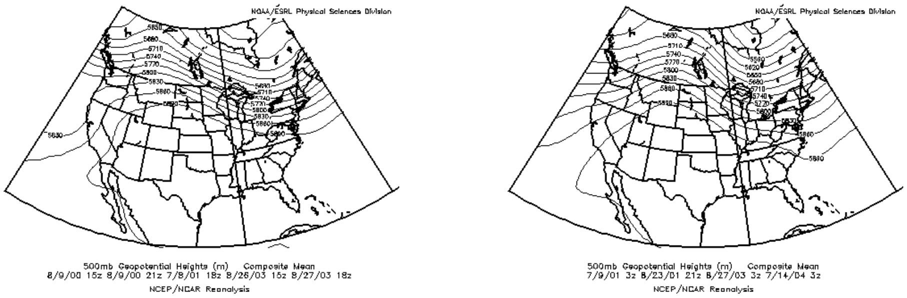
Figure 4. Same as in Figure 3, but for two special sub-categories of not-crossing cases: Penetrating (in orange) and Dissipating West (in light green).

A further breakdown of the diurnal climatology of the not-crossing cases into two of the special categories is shown in Figure 4. While the sample sizes are especially small, these data suggest that the Penetrating cases were more common in the evening and early night time hours, which is somewhat delayed from the actual crossing cases. The number of cases that dissipated even before reaching the western slopes all did so outside of peak heating hours. The two that dissipated in the early evening hours west of the mountains occurred during the cool season when loss of limited surface heating is earlier. Otherwise, the number of Dissipating West events in this data set may be too small to offer any other meaningful conclusions.

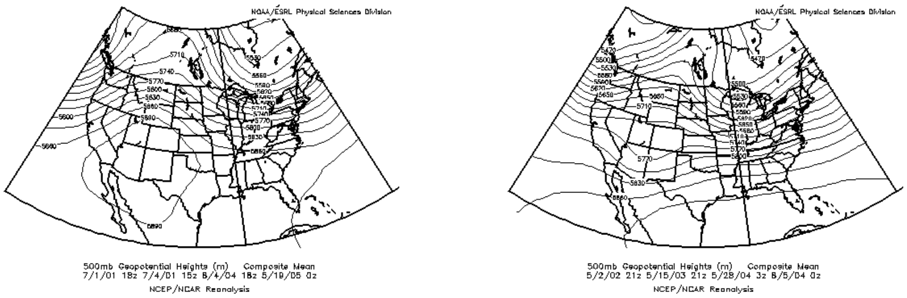
5. SYNOPTIC PATTERNS

We identified five map types, based primarily on the 500 mb patterns, which were observed for both the fundamental crossing and not-crossing categories, plus one additional unique pattern for each of the two MCS categories. The composites for each map type are shown in Figure 5 (a through l) with those generated from the crossing cases on the left side, and those from the not-crossing events on the right hand side. The number of cases used to create each composite is shown under each map. The five patterns that the two fundamental MCS categories shared were: Northwest Flow; Positive Tilt Great Lakes Trough; Short Wave Trough in Westerly Flow; Deep Progressive Midwest Trough; and Full Latitude Trough. The two unique patterns are Negative Tilt Great Lakes Trough (one crossing case), and Closed Low over Mississippi Valley (two not-crossing cases). The side-by-side comparisons reveal only very subtle differences between the crossing and not-crossing categories for each map-type. Any small differences are likely due primarily to the limited number of cases than any meaningful differences in large scale patterns that would distinguish between crossing severe MCSs and those that do not.

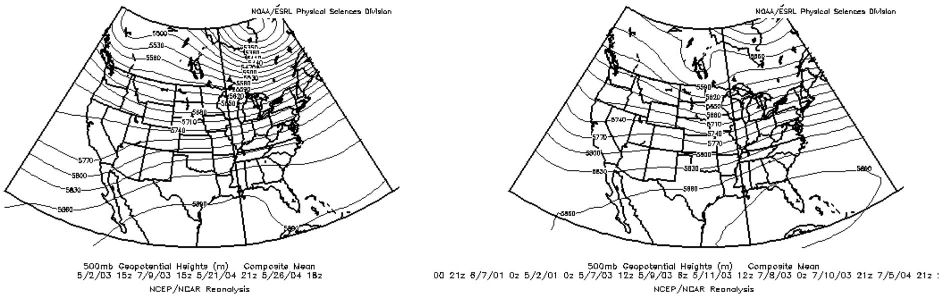
Crossing **Not-crossing**



(a) Northwest Flow (5 cases) (b) Northwest Flow (4 cases)



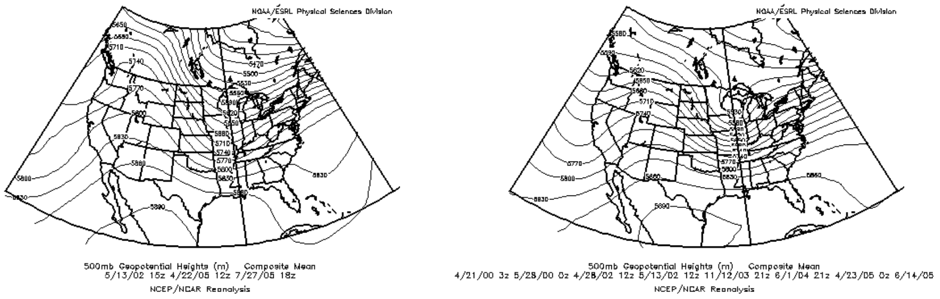
(c) Positive Tilt Great Lakes Trough (4 cases) (d) Positive Tilt Great Lakes Trough (4 cases)



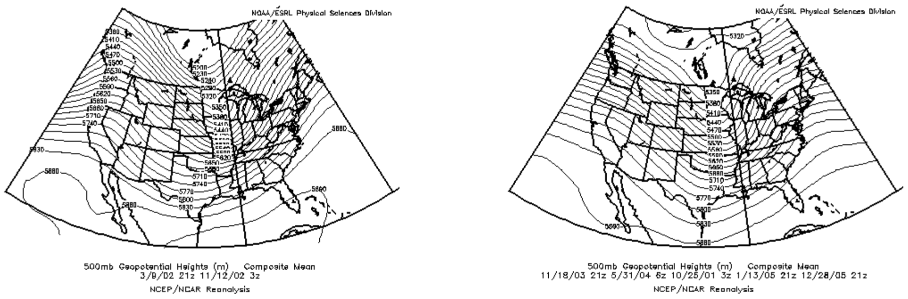
(e) Short Wave Trough in West Flow (4 cases) (f) Short Wave Trough in West Flow (10 cases)

Figure 5 (a-f). 500 mb composite maps showing geopotential height contours (interval 30 m) for the first three synoptic map-types identified for the crossing cases (left side) compared to the not-crossing cases (right side). The number of cases used in each composite is indicated. Images provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at http://www.cdc.noaa.gov/.

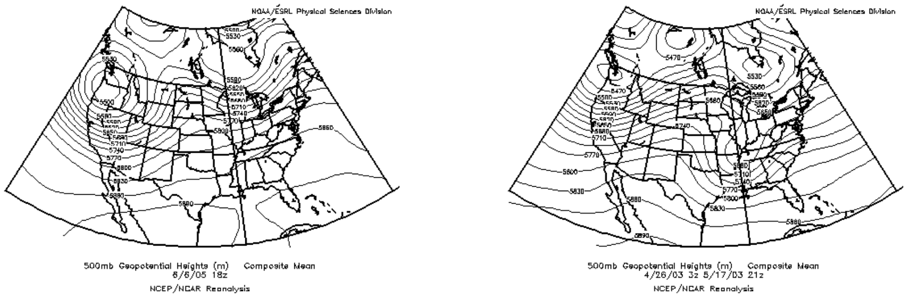
Crossing **Not-crossing**



(g) Deep Progressive Midwest Trough (3 cases) (h) Deep Progressive Midwest Trough (8 cases)



(i) Full Latitude Trough (2 cases) (j) Full Latitude Trough (5 cases)



(k) Negative Tilt Great Lakes Trough (1 case) (l) Closed Low over Mississippi Valley (2 cases)

Figure 5 (g-l). Continuation of Figure 5 for the next two synoptic map types (g-j), while bottom two map-types (k and l) are unique for their respective categories and are not meant to be compared side-by-side as with the other pairs in a-j.

The 19 crossing events are fairly evenly split between all five map types (with the exception of the very limited number in the Full Latitude Trough and the Negative Tilt Great Lakes Trough), with the highest number (5) associated with the Northwest Flow pattern. On the other hand, the 33 not-crossing cases are heavily weighted within the Short Wave Trough in Westerly Flow (10) and Deep Progressive Midwest Trough (8) map types. One implication here is that with an approaching MCS in either of these two patterns the probability is much greater that they will not cross. However, the relatively small sample size for each synoptic map type, as well as other potentially important factors, suggests this idea should be used with caution.

Perhaps the only notable difference in comparing the composites between the crossing and not-crossing categories shows up in the Positive Tilt Great Lakes Trough map type. The crossing cases show much more ridging in the Four Corners region of the western U.S. and west-northwest flow over the Appalachian region at the base of the Great lakes trough (Fig. 5c), whereas the not-crossing cases exhibit split flow over the western U.S. with a progressive wave over the Four Corners region and slightly more WSW flow over the Appalachians (Fig. 5d).
Overall, however, the differences in the patterns between crossing and not-crossing cases for their respective map-types are probably too subtle to draw any confident conclusions, especially considering that the overall number of cases for many of these composites is very small. Nevertheless, the composites can be used to help forecasters recognize the general large scale patterns favorable for severe MCS activity upstream of the Appalachians, and then consider other factors to help determine whether they are likely to cross or not.

6. ANALYSIS OF SOME EXCEPTIONS TO THE DIURNAL TENDENCIES

As discussed in the previous section, this preliminary study found that severe quasi-linear MCSs had a strong tendency to cross the Appalachians when approaching the higher terrain during the afternoon, while tending to not cross at night. However, notable exceptions over the 6-year period are briefly highlighted below, including a case in which a severe MCS crossed the Appalachians at night, and one that failed to cross during the typical peak afternoon hours.

6.1 Nocturnal Appalachians-Crossing MCS Cases

From this study, five cases were identified as Appalachians-Crossing MCS cases with organized severe weather occurring during the evening, and even into the overnight hours in a few instances. The cases are: 9 August 2000; 9 March 2002; 10 November 2002; 21 May 2004; and 19 May 2005. Each of these cases exhibited moderate to strong instability at night in and to the east of the mountains (>1500 J/kg 100 mb mixed-layer Convective Available Potential Energy; hereafter MLCAPE), and/or a well organized mesoscale cold pool. For illustrative purposes, the secondary derecho of the 9 August 2000 “dual derecho” event is briefly discussed below, which exhibited both of these characteristics.

9 August 2000

In a “Northwest Flow” synoptic pattern regime, and in the wake of an early day derecho that produced widespread severe weather from Indiana and Ohio into much of Virginia, a secondary derecho developed during the late afternoon hours across southern Ohio. The derecho moved south-southeastward, producing an additional bout of widespread damaging winds and hail during the evening and overnight as it crossed the Appalachians (Figures 6 and 7). A very warm and moist airmass was in place ahead of the secondary nocturnal derecho, with surface dewpoints in the 70s ^{o}F (03 UTC surface plot – Figure 8). The 00 UTC observed sounding from Blacksburg, VA (KRNK) was representative of the strong instability that was in place in the central Appalachians during the early evening hours, with MLCAPE in excess of 3000 J/kg and steep mid level lapse rates atop a moisture laden boundary layer (Fig. 9). The unusually moist and unstable airmass appeared to maintain a favorable environment for forward propagation of this nocturnal derecho as it crossed and moved east of the Appalachians after dark. For a more thorough discussion of this event, see Keighton et al. (2001).

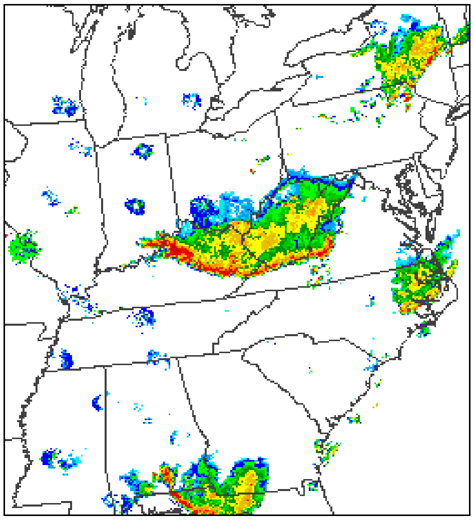


Figure 6. 0300 UTC 10 August 2000 Regional WSR-88D Composite Reflectivity.

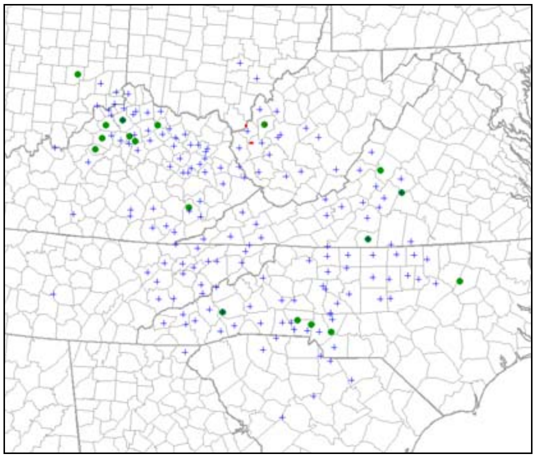


Figure 7. Observed severe weather reports from 00 UTC 10 August 2000 to 12 UTC 10 August 2000. Green dots denote reports of large hail (> 0.75 inch), blue crosshairs are reports of damaging winds or wind gusts in excess of 50 knots, with tornadoes represented by red dots.

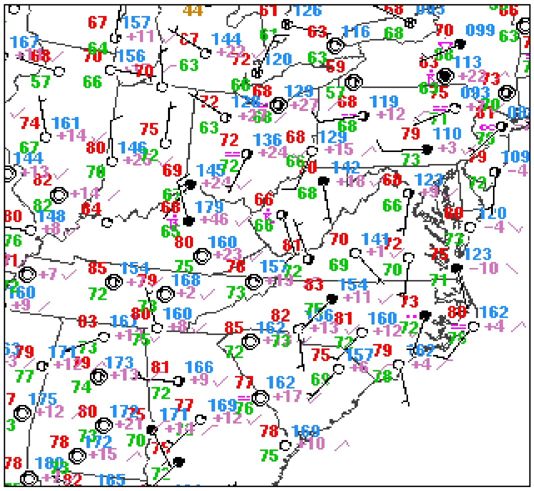


Figure 8. 10 August 2000 03 UTC standard surface plot with MSLP (blue), temperature (red), and dewpoint (green).

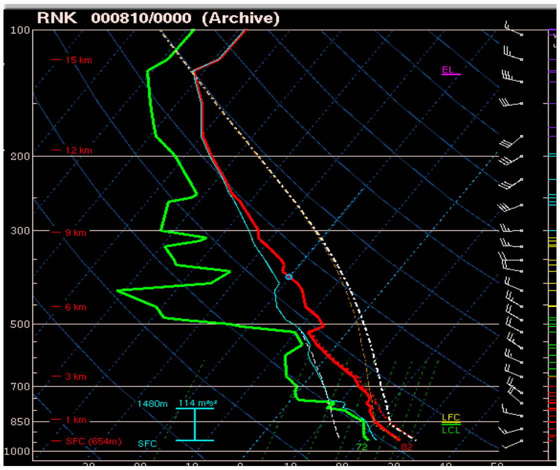


Figure 9. 10 August 2000 00 UTC observed sounding from KRNK on Skew-T Log-P diagram, with temperature profile (red), dew point profile (green) lifted surface parcel adiabat (white-dashed), mixing ratio (blue dashed) and the effective inflow layer (blue solid).

6.2 Cold Air Damming

Another exception to the diurnal crossing tendency were days with strong cold air damming (CAD – Bell and Bosart 1988), during which cool/stable low-level conditions were persistent along and east of the Appalachians. Two cool season cases in this study were noted when CAD persisted in the lee of the Appalachians. Cool and stable conditions considerably limited the MCS longevity and severity across the Appalachians during these events, even when factors as diurnal timing and large scale forcing via a shortwave trough were otherwise favorable. The two events were 18 November 2003 and 21 February 2005, the second of which is briefly discussed below.

21 February 2005

On 21 February 2005, a well organized severe weather-producing MCS neared the western slopes of the southern Appalachians before noon local time (~17 UTC – Figure 10). This MCS was occurring along and just ahead of a synoptic cold front and a low amplitude shortwave trough embedded within strong west-southwest upper flow (the “Short Wave Trough in Westerly Flow” synoptic regime). The northern and central portion of the MCS quickly diminished in intensity during the afternoon, seemingly as it encountered CAD east of the Appalachians. No severe reports were received the afternoon of 21 February 2005 northeast of northern Georgia (Figure 11). North of a wedge front across northern Georgia and South Carolina, cool temperatures in the 50s ^{o}F (Fig. 12) and limited convective instability prevailed through the afternoon across most of the Carolinas. This is illustrated by less than 100 J/kg MLCAPE at observed morning (12 UTC) and evening (00 UTC) soundings from Greensboro, NC (Fig. 13).

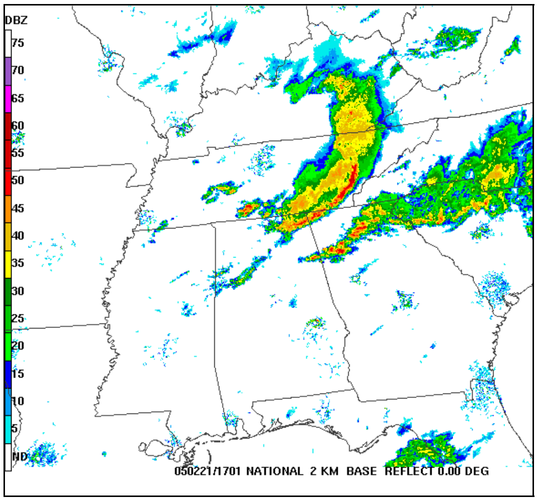


Figure 10. 1701 UTC 21 February 2005 Regional WSR-88D Composite Reflectivity.

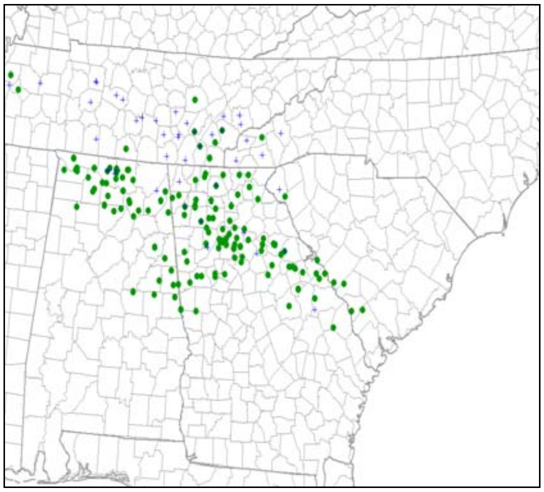


Figure 11. Same as Figure 7, but for 12 UTC 21 February 2005 to 12 UTC 22 February 2005.

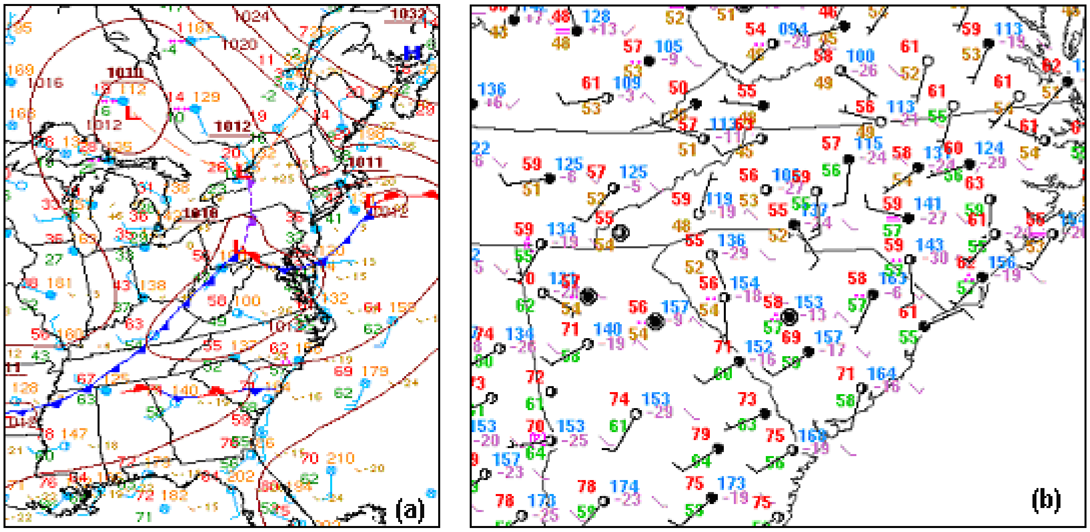


Figure 12. 21 February 2005 21 UTC surface maps. (a) HPC frontal analysis and (b) standard surface plot with MSLP (blue), temperature (red), and dewpoint (brown or green).

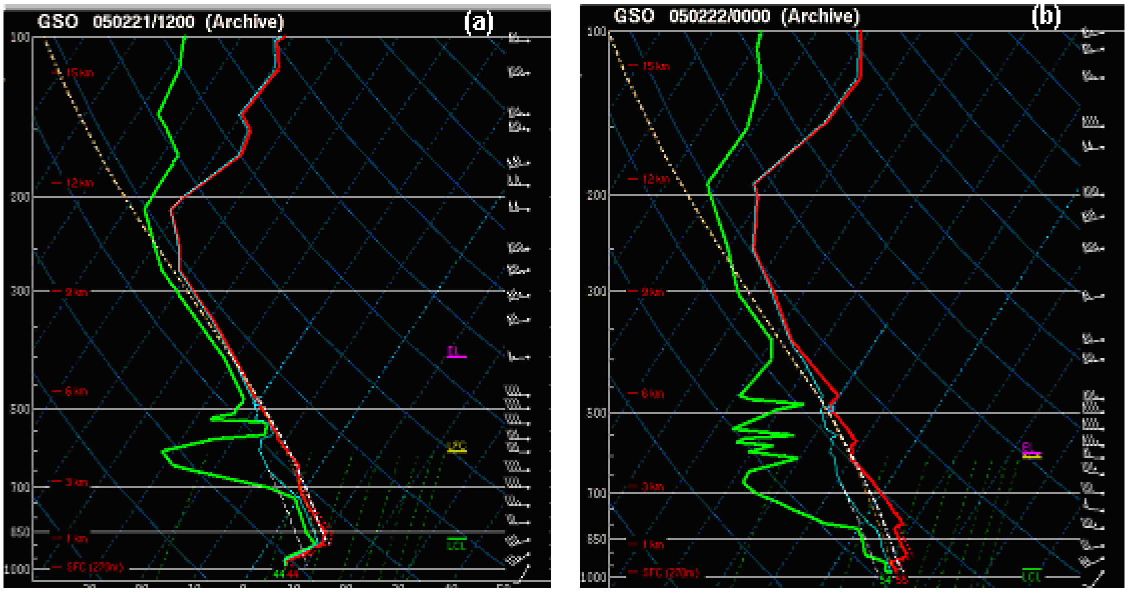


Figure 13. Same as Figure 9 except (a) 21 February 2005 12 UTC observed sounding from KGSO; (b) 22 February 2005 00 UTC observed sounding from KGSO.

7. CONCLUSIONS

The motivation behind this study was to establish an observationally-based database of favored climatology and synoptic patterns for severe MCSs which survive across the central and southern Appalachians into the Piedmont regions. The six year period of study (2000 – 2005) included 52 severe quasi-linear MCS cases that moved into or formed in the western portion of the study domain. Of these 52 cases, 19 continued to produce severe weather across the mountains and into the Piedmont. Of the remaining 33 which did not cross the Blue Ridge, 12 were classified as "Penetrating", meaning they produced a number of severe weather reports in the Appalachian zones but did not continue to cross the mountains. Therefore, there were actually a higher percentage of severe MCSs that crossed or moved part way through the mountains compared to the number that dissipated on the western fringes or further west.

Favored 500 mb synoptic scale patterns are generally very similar between the crossing and not-crossing cases, with subtle differences likely to have more to do with the limited sample size than any meaningful differences. Forecasters should be aware of all these general patterns that support severe MCS activity immediately upstream of the Appalachians to anticipate their development, and then consider other factors, such as those discussed below, to help determine the likelihood of them crossing the Appalachians.

Seasonal climatology shows a strong tendency for severe MCSs to approach the Appalachians during the warm season months of May through August. Crossing cases are equally as likely as not-crossing cases in the two months of July and August, although the sample size in this six-year period may not be large enough to make a definitive conclusion in this regard. Diurnal climatology shows a strong afternoon/evening maximum in overall severe MCS frequency in this region, but crossing cases are far more likely from midday through late afternoon compared to not-crossing, while not-crossing cases are most likely in the late evening hours. Only a handful of not-crossing cases reached the western slopes or dissipated to the west during the overnight and morning hours. "Penetrating" cases (those that almost crossed) were observed most often in the late evening hours. *Therefore, there is a strong signal that the greater instability generated from daytime heating is a major factor in determining whether severe MCSs can cross through the Appalachians. Thus the timing of these systems reaching the western slopes of the mountains appears to be a critical factor in forecasting their ability to cross or not.*

Analysis of some exceptions to the typical diurnal tendencies further confirms the importance of instability over and to the east of the Appalachian region. The handful of cases which crossed after peak heating either exhibited unusually high instability for late at night, and/or managed to develop impressive cold pools inferred by their radar appearance as they approached the mountains from the west. The two not-crossing cases which occurred in the afternoon both were during the cool season, and both encountered stable air over and east of the mountains due to the presence of CAD.

8. DISCUSSION AND FUTURE WORK

There is a well documented nocturnal maximum in MCS events in the central part of the country (see Parker and Ahijevych, 2007 for a good summary of these studies), which is largely due to the formation of a more frequent and stronger low-level jet in the lee of the Rockies compared to east of the Appalachians (Zhang et al. 2006). Therefore, one can speculate that a large percentage of severe MCSs moving eastward away from the central U.S. would tend to decay with the loss of heating whether the Appalachians were present or not. We suggest this indeed might be the case to some extent, however the generally lower instability observed in the higher elevations of the Appalachians as well as the frequent influences of this terrain feature on generating low-level stable layers in and east of the mountains (CAD events) act to enhance this tendency even more. Furthermore, shallow cold pools traversing the relatively flat terrain of the Plains and into the Ohio Valley may still be able to produce enough lift to overcome surface-based inversions after sunset. However, the nature of the complex terrain of the Appalachians may act to disrupt all but the most intense and deep cold pools enough to prevent the lift from overcoming the inversion. Numerical simulation work by Frame and Markowski (2006) on idealized ridges suggests this could be an important factor in this region.

These speculations will require much more detailed analysis of observational data for all of these cases, as well as an array of numerical simulations on specific cases to help confirm or deny these ideas. The intention is to continue this study by pursuing those kinds of efforts.

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