Reprinted from: November 1993 *Bull. Amer. Meteor. Soc.*, **74**, 2213–2218

Comments on "Anomalous Cloud-to-Ground Lighting in an F5 Tornado-producing Supercell Thunderstorm on 28 August 1990"

In his very interesting presentation of the cloud-to-ground (CG) lightning characteristics of the storm of 28 August 1990 that devastated Plainfield, Illinois, Seimon (1993, hereafter S93) has arrived at some interpretations of the events with which we want to take issue. We believe that the Plainfield storm event may be less anomalous than Seimon has indicated and we shall endeavor to present ideas that might illuminate the events of that day. We too believe that there are some extraordinary aspects of the Plainfield storm that simply cannot be explained away, as indicated by Seimon's Fig. 2. However, based on the sample of tornadic storms for which we have CG lightning strike data, we believe Seimon's suggestion of a "probable association between the dynamical aspects producing tornadogenesis and electrical activity in the parent thunderstorm" is premature, since significant exceptions to the character shown by the Plainfield storm can be found, even on 28 August 1990, as it turns out.

Our first point concerns the assertion in S93 that "mesocyclone formation and tornadogenesis occurred near the leading edge of the southeast-moving storm, and not in the more commonly-observed rear-flank location." It is hard to understand how such a conclusion can be justified based on the data shown in the paper. Figure 6 in S93, showing the evolution of the radar echo, reveals a clear indication of either a "pendant" or "hook" echo on the storm's southwestern flank. For reasons we shall attempt to explain later, the forward flank downdraft area (as discussed in Lemon and Doswell 1979) does not extend very far in advance of the storm, but the low-level reflectivity structure [systematic volumetric scanning of the storm was not done (U.S. Department of Commerce 1991) for this event] seems quite consistent with the basic pattern described in Lemon and Doswell (1979). Given the storm's southeastward movement, the position of the mesocyclone and tornado fit the basic supercell pattern quite well. Therefore, we do not agree with an interpretation that places the mesocyclone and tornado on the "leading edge" of the storm.

A second point of disagreement concerns the assertion that "While several storms formed regionally with the same environment, the Plainfield storm was the lone tornado producer." In fact, the storm that caused the lightning in southwestern Ontario, Canada (predominantly *negative* CG flashes), and then crossed Lake Erie produce a strong (F3) tornado that was on the ground for about 20 min and devastated the town of Frome, Ontario. This storm was almost certainly a supercell (B. Murphy 1993, personal communication), and produced another tornado (rated F2). We shall return to this storm later, but for the moment, it suffices to note that the Plainfield storm was *not* the lone tornadic storm, and it is of significance to note that the Canadian storm's CG lightning activity is not markedly different from other storms of that day and definitely bears no resemblance to the remarkable lightning signature of the Plainfield storm.

The discussion of the Peoria, Illinois sounding at 0000 UTC on 29 August 1990 has a number of problems. It is somewhat risky to consider the sounding as entirely representative of the event, since Peoria is well behind the convective storms at 0000 UTC. While the entire region was characterized by high lapse rates and considerable low-level moisture, both of which contributed to the very high convective available potential energy (CAPE) values, it is not obvious that the wind profile (from which helicity was estimated in S93) is representative of the near-storm environment in advance of the Plainfield storm. Unfortunately, it is not possible to know clearly what that prestorm environment looked like; there is no suitable proximity sounding. At the very least, this suggests that readers should be cautious in accepting uncritically the assertion that the 0–2-km storm-relative helicity was as low as S93 suggests. In fact, at 700 mb at 1200 UTC (Fig. 1), substantially stronger winds could be seen upstream, over Minnesota. It is possible that the Plainfield storm experienced somewhat larger 0–2-km storm-relative helicity than analyzed in S93 directly from the 1200 UTC Peoria sounding. Note that the value of 107 $m^2\ s^{-2}$ reported by LaPenta (1992) and cited in S93 is for the unmodified sounding with the observed storm motion (Fig. 2). The presence of large gradients in winds (apparent at 700 mb, Fig. 1) makes the production of a proximity hodograph difficult, at best, but it surely is plausible that the environment in the vicinity of the storm differed from that shown in the 1200 UTC Peoria observation. While we choose to refrain from doing so, Korotky et al. (1993) have constructed a postulated proximity hodograph that yields a slightly larger 0–2-km storm-relative helicity of 147 $m^2\ s^{-2}$.

As for the "threshold" values for the helicity given in Davies-Jones et al. (1990; hereafter DBF90), readers are urged to read the caveats in that paper carefully: the dataset used was limited (only 28 tornadoes) and the values given for "thresholds" are stated to be preliminary and rough, not firmly established. Whatever else one might say about the Plainfield storm, there can be no denying it had a substantial mesocyclone, so either the storm experienced helicity greater than the DBF90 mesocyclone threshold or that threshold must not be taken as an impenetrable barrier, with all mesocyclones exceeding the thresholds and no mesocyclonic storms failing to meet the so-called threshold. We believe that the values given in DBF90 should be used as guidelines, not thresholds. In fact, it is clear from Fig. 5 of S93 that strong and violent tornadoes in environments having storm-relative helicity values less than 140 $m^2\ s^{-1}$, while not common, occur with sufficient frequency that using the guidelines suggested in DBF90 as thresholds for tornado forecasting is unwise. Further, a physical interpretation of the role of helicity leads only to the development of mesocyclones aloft and not to tornadoes, except by association with mid-level mesocyclones.

Moreover, DBF90 measured helicity in the layer from the surface to 3 km, not the 0–2-km layer. This may not be a very important point at those times when thee majority of the helicity is contained in the lowest part of the wind profile. The choice of an averaging depth may be of particular relevance in this case, however, since in the 1200 UTC Peoria wind profile, the winds above 2 km back (in a storm-relative sense), so the contribution to storm-relative helicity above about 1 km is negative. Davies-Jones and Zacharias (1988) and McCaul (1993) have noted that storm-relative helicity in the lowest part of the sounding may be the

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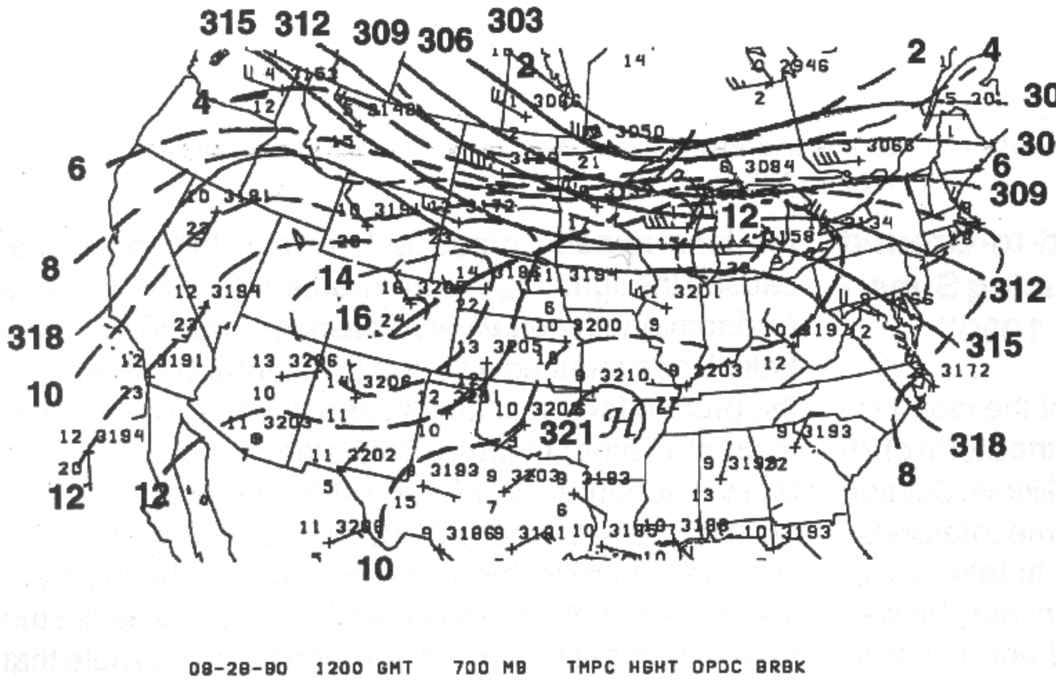

Fig. 1. Analysis at 700 mb, 1200 UTC on 28 August 1990; the solid lines show geopotential height contours (at 30–dam intervals), while the dashed lines denote isotherms (at 2ºC intervals). The station plot is conventional.

most important. As it turns out for the 1200 UTC Peoria wind profile, Fig. 3 shows that in the lowest 500 m the helicity is as high as 188 $m^2\ s^{-2}$, without even considering the possible effects of the stronger 700 mb winds north of Peoria seen in Fig. 1. This still is not a large values but it is about 80% larger than the value given in S93 and surpasses the low “threshold” given by DBF90 as sufficient for a mesocyclone.

Yet another issue we have concerning the evaluation of the 0000 UTC sounding at Peoria is the determination of CAPE. The very large value of “about” 8000 J kg^{-1} mentioned in S93 is based on lifting the *surface* parcel. As we have calculated CAPE using the surface parcel, we indeed find a value of 7991 J kg^{-1} (See Fig. 4). However, as noted quite recently by Williams and Renno (1993), the value computed for CAPE can be very dependent on *which* parcel one chooses to lift. In S93’s Fig. 5, the plotted CAPE values were all computed using a parcel representing the average potential temperature and mixing ratio in the surface layer of the sounding. Some caution should be exercised in comparing CAPE values; if some measure of consistency is desired, all CAPEs need to be computed the same way.

When we use the lowest 50-mb average properties for the sounding in question, as shown in Fig. 4, we obtain a CAPE of 5873 J kg^{-1}, which is still a large value but when plotted in Fig. 5 of S93 no longer represents an extraordinary “outlier.” In the case of the sounding, the very high lapse rate of wet-bulb potential temperature in the surface layer results in a significant decrease of CAPE when considering parcels above the surface. We observe that large CAPE (exceeding 4000 J kg^{-1}) is almost always the result of a combination of two aspects of the sounding: high absolute humidities in the lowest levels and steep lapse rates above the moist layer. Such steep lapse rates are virtually impossible to obtain in moist air (as discussed in Doswell et al. 1985), so the lower midtropospheric steep lapse rates are associated with dry air. The high absolute humidities in low levels ensure that the moist adiabat along which parcels ascend will be relatively far to the right on a thermodynamic diagram, where the difference between the dry and moist adiabats is large. But the low relative humidities and steep lapse rates aloft result in a rapid decrease of wet-bulb potential temperature with height in such cases, as observed here.

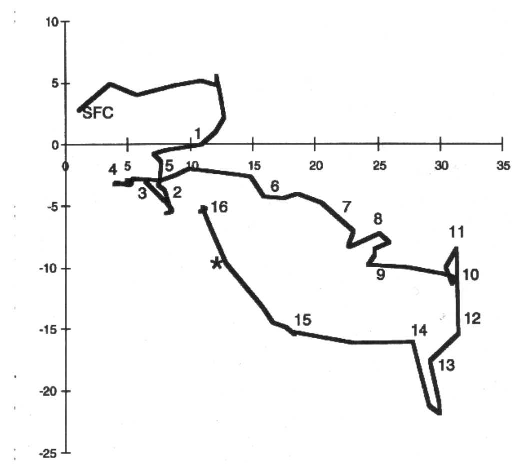

Fig. 2. Observed hodograph from Peoria at 1200 UTC 28 August 1990. Axes are labeled in m s^{-1}, while the larger labels along the hodograph denote heights in km, and storm motion is indicated with an asterisk.

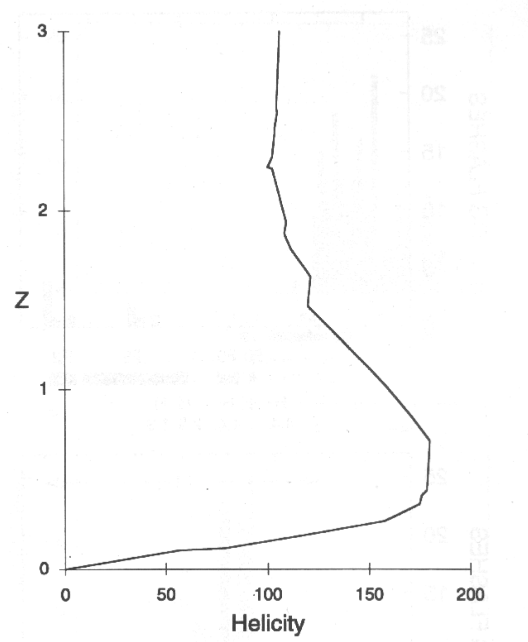

Fig. 3. Plot of storm-relative helicity ($m^2\ s^{-2}$) as a function of height from the 1200 UTC Peoria sounding on 28 August 1990.

It appears from Fig. 6 in S93 that the transition from a high percentage to a low percentage of positive CGs occurs during the transition period where the reflectivity hook wraps around the south-southwest flank of the storm. This behavior can be interpreted as the result of the storm's mesocyclone wrapping precipitation around itself. Earlier on in the storm's lifecycle, either the storm did not have a mesocyclone, or if a mesocyclone was present,[1] its flow was not capable of pulling precipit a-tion around itself. Although the reasons for this transition are not known, the presence of substantial amounts of precipitation in and around the storms updraft may have had a significant effect on the character of the lightning. Branick and Doswell (1992) have suggested that high-precipitation (HP) supercell storms may be less likely to produce a significant fraction of positive CG flashes, for reasons that are not at all obvious at this point. It may be that the evolution of the Plainfield storm into an HP supercell is the primary explanation for the observed abrupt transition in CG lightning activity.

In HP supercells, a considerable amount of precipitation produced aloft is wrapped around the mesocyclone. If this storm indeed has a mesocyclone at middle levels, as the wrapping up of the hook suggests, then less precipitation is available to be swept downstream by the middle- and upper-tropospheric storm-relative winds than in a storm *without* a mesocyclone. Thus, it is possible that the storm's precipitation cascade into the forward flank downdraft is inhibited by the mesocyclone, resulting in the reduced extension of the radar echo ahead of the storm, as mentioned earlier. The amount of precipitation pulled from the precipitation cascade by the mesocyclone depends on the tangential velocity of the mesocyclone and the storm-relative flow at the levels where the mesocyclone exists. In fact, we believe this is the basic mechanism by which HP supercells form; they are supercells for which the mesocyclonic flow may be comparable to or stronger than the storm-relative flow at mesocyclone levels. As more precipitation is wrapped around the back side of the mesocyclone (forming the hook), it is likely that it enhances the downdraft on the back side of the storm; that is, all of this precipitation would be falling into relatively dry environmental air with a steep lapse rate, creating the series of downbursts preceding the major tornado. This process of enveloping the mesocyclone in precipitation may have some impact on lightning activity (as observed by Branick and Doswell 1992), but that issue is beyond the scope of these comments.

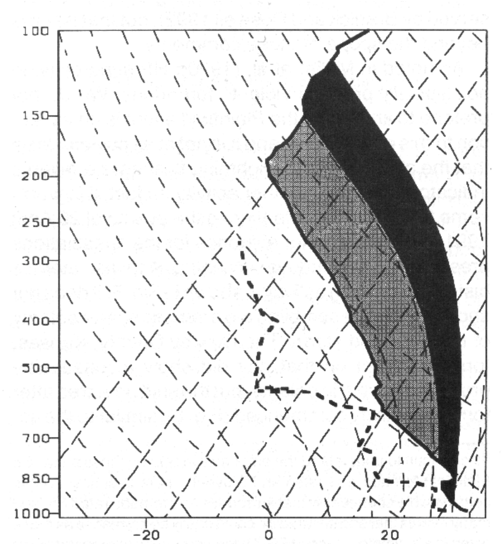

Fig. 4. Skew T−log*p* plot of the 0000 UTC Peoria sounding on 29 August 1990, showing the ascent curves for a surface parcel and for a parcel having the average potential temperature and mixing ratio in the lowest 50 mb. Light shading indicates the positive area associated with the lowest50-mb parcel, and dark shading indicates the additional area for the surface parcel

As noted in Moller et al. (1990), HP supercells do not *typically* produce violent[2] tornadoes. We do not pretend to know what the Plainfield event is an exception to this observation, and it is not at all obvious to us that the character of the lightning flashes is a reliable indicator of severe weather activity. In fact, it is worrisome that S93 calls attention to the events of 26 April 1991 to provide further evidence for the speculations presented. The Andover-Wichita, Kansas, storm's history of lightning activity is shown in Fig. 5. It does not show anything resembling the dramatic shift in polarity of the Plainfield storm. The Cowley County, Kansas, tornadic storm on that day did show a reasonably pronounced shift in polarity, but the shift occurred after

[1] In the absence of volumetric scans and/or Doppler radial velocity fields, it is difficult to resolve whether or not a mesocyclone was present earlier. Whereas the hook is unmistakable evidence of a mesocyclone, the absence of a hook is not sufficient evidence to deny the existence of a mesocyclone, at least aloft. The earlier occurrence of a tornado near Rockford, Illinios, certainly suggests that a mesocyclone might well have been present (at least aloft) through much of the storm's lifetime.

[2] It is difficult to understand the emphasis in S93 on the fact that the Plainfield tornado was rated an F5 event. There is almost always considerable controversy that surrounds any tornado rated F5, and many events that end up rated F4 could easily be as intense as those given the "ultimate" rating of F5. These comments are not the place for a discussion of the F-scale ratings (see Doswell and Burgess 1988), and we do not think it is prudent to generalize about the characteristics of rare storms that are given the F5 rating. Had the author looked at tornadoes rated as "violent" (*either* F4 or F5), then the putative relationship to CG lightning flash activity would not have been sustained.

tornadic activity commenced (Fig. 6), similar to the so-called Red Rock, Oklahoma, storm (Fig. 7). A fourth tornadic storm that struck Oolagah, Oklahoma (Fig. 8), did not ever have a significant amount of +CG activity, with –CG activity dominating throughout. It is hard to

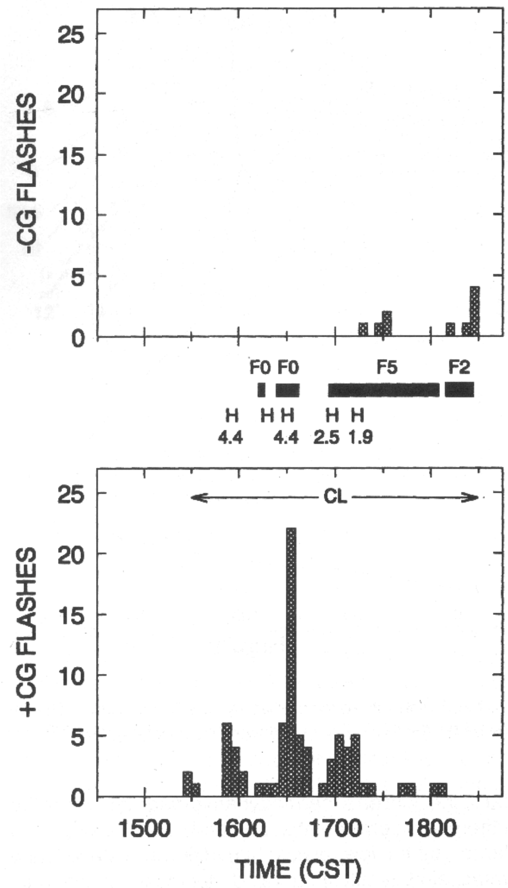

Fig. 5. Time series plot of the positive (+) and negative (-) polarity CG lightning flashes for the Wichita–Andover tornadic storm on 26 April 1991; also shown is the time of occurrence of tornadoes (solid horizontal lines, with official F-scale ratings) and reported hail occurrences (denoted by "H" with diameter in cm). The letters "CL" indicate subjective extent of classic supercell structure. From MacGorman and Burgess (1993), used by permission.

imagine how one might draw a conclusion about the relationship between CG lightning activity and "tornado-producing dynamics" from these four storms on the same day, all of which produced violent tornadoes and were at least arguably within a similar setting.

The tornadic storm in Ontario is of interest for this paper because it is erroneously excluded in the discussion of S93 and because of the apparent contrast (in terms of its CG lightning activity) to the Plainfield storm. The environments, as captured by the standard upper-air network, were similar. Based upon the 1200 UTC sounding from Flint, Michigan, it developed in an environment that was less unstable, with a CAPE of approximately 4000-4500 J kg^{-1} with modifications for surface conditions in the afternoon. It had somewhat more storm-relative environmental helicity than the Plainfield storm (approximately 210 m^2 s^{-2} for the 0–500-m layer, compared to the 188 m^2 s^{-2} for Plainfield, and 186 m^2 s^{-2} for 0–3 km) and with similar or slightly weaker storm-relative wind magnitudes through

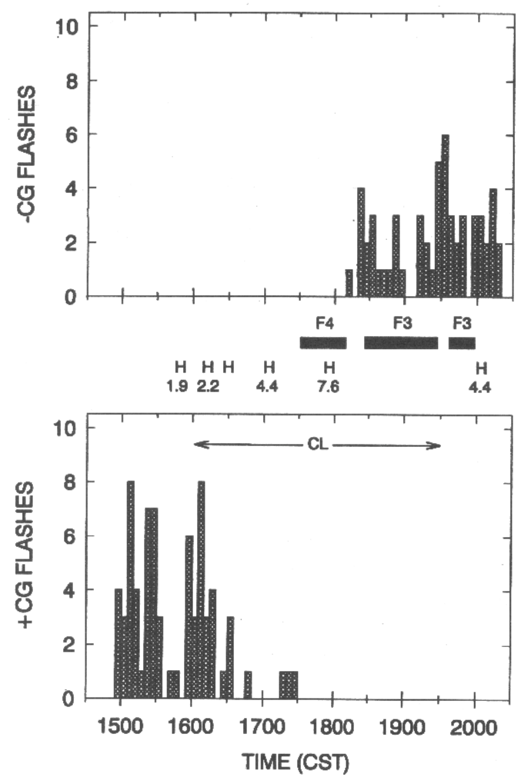

Fig. 6. As in Fig. 5, except for the Cowley County storm.

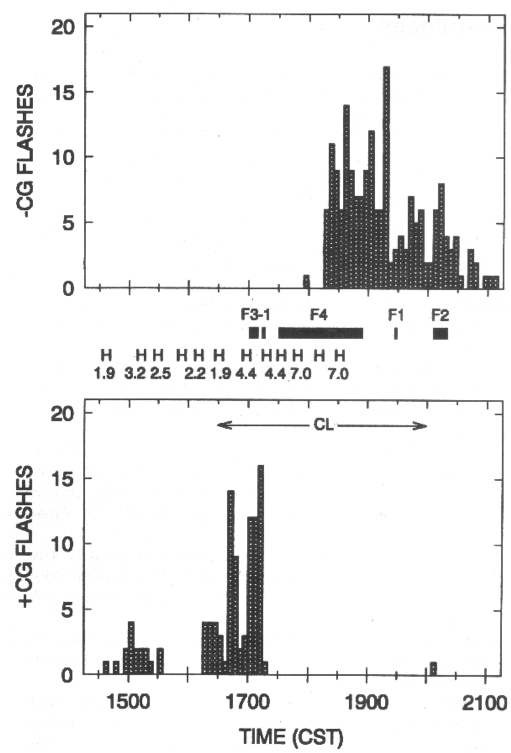

Fig. 7. As in Fig. 5, except for the Red Rock storm

the troposphere. This supercell produced at least two separate tornadoes, one west of London, Ontario, and the other west of St. Thomas, Ontario. It is the latter tornado that demolished 80% of the buildings in the small town of Frome, Ontario. Not only was this storm markedly different from the Plainfield storm in its lightning activity, its *impact* was also quite different, because the Ontario Weather Centre issued excellent warnings for the storm and most of the citizens in Frome sought shelter. As a result, there was only one injury in Frome. Had there been a large casualty figure associated with this tornado, this event might not have escaped attention. Given the impact of the Plainfield storm and the fact that it occurred in another country, this oversight is understandable, if not excusable.

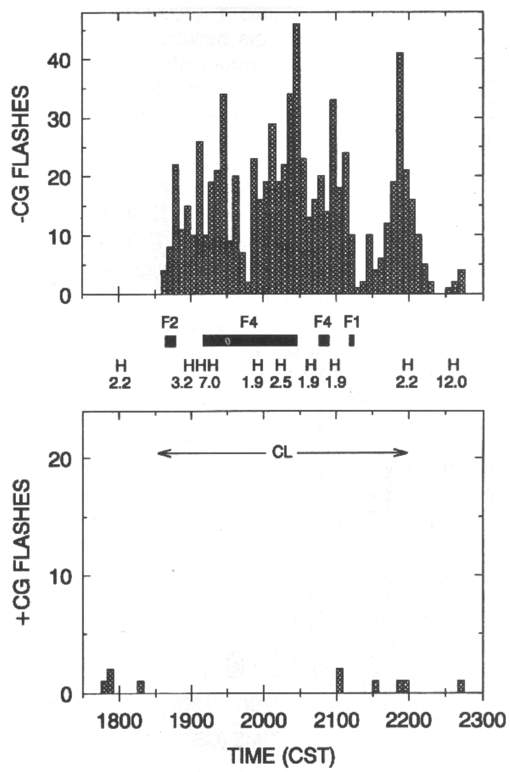

Fig. 8. As in Fig. 5, except for the Oolagah storm.

Acknowledgments. We wish to thank Mr. Brian Murphy (Atmospheric Environment Service, Ontario, Canada) for his help in providing information about the 28 August 1990 events in Ontario. Also, we appreciate Dr. Don MacGorman (NSSL) for sharing his figures, which show lightning activity on 26 April 1991.

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Charles A. Doswell III and Harold E. Brooks
NOAA/ERL, National Severe Storms Laboratory
Norman, Oklahoma