

SUSPENSION OF AN INTERCOLLEGIATE FOOTBALL GAME DUE TO LIGHTNING

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ABSTRACT

On 18 September 2004, a nationally-televised college football game between the University of Wisconsin and the University of Arizona (UA) was suspended for 88 minutes because of lightning. This was the first intercollegiate football game ever stopped in progress at the UA, and this incident has raised important questions about how the “30-30 rule” for lightning safety should be implemented. We will describe the meteorological conditions that produced thunderstorms on that afternoon, the lightning that led to a suspension of play, and the decision-making process relative to the NCAA lightning safety guidelines.

The suspension was caused by thunderstorms that developed from Tropical Storm Javier interacting with a trough to the northwest. Javier brought abundant low-level moisture into southern Arizona, and the associated thunderstorms grew quickly and reached Tucson in the early afternoon.

The game started at about 1305 MST, and was halted a few minutes after cloud-to-ground (CG) lightning was detected within 6 miles/9.6 km of the football stadium, a distance criterion that is recommended by the “30-30 rule” in a guideline published by the NCAA. In this rule, the first 30 refers to the number of seconds between seeing a flash of lightning and hearing the associated thunder. The second 30 refers to the number of minutes that one should wait before resuming outdoor activities.

As the thunderstorms approached the stadium, UA officials contacted the National Weather Service (NWS) Forecast Office located 700 m from the stadium every 15 minutes, and they received updates on the CG lightning that was detected by the U.S. National Lightning Detection Network (NLDN). An electric field sensor on the UA campus about 500 m from the stadium provided a history of the cloud electric field, but these data were not available at the NWS office in real time.

Just after play was resumed, a large cloud discharge occurred directly over the stadium, and

because of this and the high electric fields that were present at the time, it is clear that play was resumed 30 to 45 minutes too soon. Two additional CG flashes struck within 11.3 and 7.1 miles/18.2 and 11.3 km of the stadium in the next 15 minutes, and these flashes have called our attention to an end-of-storm ambiguity in the present 30-30 rule that will require further study.

1. INTRODUCTION AND BACKGROUND

In 1997, the National Collegiate Athletic Association (NCAA) published some guidelines for lightning safety during outdoor sports activities in its annual *NCAA Sports Medicine Handbook* for the 1997-98 school year (Ref. 4). This was followed a year later by an update for the 1998-99 school year (Ref. 5). The bases for the NCAA lightning policy were several studies published by the athletic trainer community beginning in 1996 (Refs. 3,17,18,19).

Subsequent to the initiatives taken by the NCAA, a meeting of an *ad hoc* Lightning Safety Group was held in 1998 at the Annual Meeting of the American Meteorological Society (AMS) in Phoenix, Arizona (Ref. 10). This group consisted of people with a broad range of interests in lightning safety, such as sports and medical staff, researchers, educators, forecasters, and others who had a strong interest in improving lightning safety policies (Ref. 10). This meeting expanded the original NCAA policy to include other situations, and several papers have been published on the outcome of this meeting (e.g. Refs. 10,20,21). In 2003, the AMS published a Statement supporting the recommendations that were developed at the Phoenix meeting (Ref. 1).

One of the primary outcomes of the meeting in 1998 was the “30-30 rule” for lightning safety. There are two parts to this rule:

- The first 30 refers to the number of seconds between seeing a flash of lightning and hearing the thunder, the so-called “flash-to-bang” method of distance-ranging, that provides a measure of when the lightning is close enough to be viewed

as dangerous. A 30-second count corresponds to a distance of about 6 miles/9.6 km which has previously been shown to include about 80% of the subsequent flashes in a thunderstorm (Refs. 14,16). This distance is a conservative but not absolutely safe distance, particularly considering the time required to evacuate a large football stadium when storms are approaching.

- The second 30 in the 30-30 rule refers to the time that people should wait before resuming outdoor activity after the last lightning is seen or thunder is heard, and the 30-minute count is re-started if any subsequent discharge occurs in the area (Ref. 16).

A recent study of the proximity of cloud-to-ground (CG) lightning flashes, as detected by the U. S. National Lightning Detection Network (NLDN) (Ref. 13), to hundreds of lightning deaths and injuries has determined that about half of the casualties occurred in situations where there were frequent CG flashes before the incident. The other half occurred when there was a much lower flash rate, or no prior cloud-to-ground lightning. The latter class of cases could be anticipated to some extent by other means such as radar reflectivity, observations of the sky, and/or electric field measurements.

The lightning threat at the 50 largest college football stadiums in the U.S. has recently been examined, and incidents at Virginia Tech (2000) and the University of Florida (2002) have been described (Refs. 6,8,9). In the Virginia Tech case, lightning occurred just before a game was scheduled to be televised nationally, and the game was not started because of frequent CG flashes in the area. In the Florida event, an alert was provided to game officials when lightning came within 10 miles/16 km, and the game was stopped and then resumed based on CG flashes within 6 miles/9.6 km. The multi-stadium study also pointed out the wide range of lightning policies that are currently in place at universities, and emphasized that planning, communication, orderly crowd control, and facility protection are the key elements of a lightning safety plan (Refs. 8,9). However, many universities have yet to implement such a plan. Similar issues related to lightning safety during outdoor sporting events have been addressed in Australia and Brazil (Refs. 2,7,15).

Lightning casualties during mainly amateur baseball, soccer, and golf games have been considered (Refs. 11,12). A small sample of incidents shows that the same issues addressed in the NCAA policy are also relevant in those sports. Soccer games tend to be played despite the presence of rain, and multiple lightning-caused deaths and injuries have occurred. Baseball games are usually halted when there is rainfall, but some

games have continued despite the presence of lightning, and deaths and injuries have resulted. In most golf situations, the individual participants or spectators are responsible for their own personal safety. But about half of all golf incidents occurred while the victims were in the process of seeking safety, i.e. when they stopped under a tree or inside an unprotected building on the course, because it was too late to reach a safe place. In all these sports, some incidents occurred when people returned to the playing field or course too soon and the lightning was not completely finished.

In this paper, we will examine the case of an intercollegiate football game that was suspended due to lightning in Tucson, Arizona in 2004.

2. TROPICAL STORM JAVIER

The thunderstorms that caused the game suspension were caused by Tropical Storm Javier that originated off the west coast of Africa in late August, and moved across the Caribbean and Central America. It reached hurricane status on 12 September. At this point, Javier was the strongest hurricane over the North Pacific in the 2004 hurricane season. The track is shown in Figure 1.

On 18 September, Javier had become a Tropical Depression as it interacted with a trough to the northwest, and was centered off the west coast of Baja California. The mid-level moisture from Javier spread to the northeast over northern Mexico and southern Arizona on the morning of 18 September (Figure 2). The Tucson upper-air sounding switched from moderately moist northeast flow in the late morning to substantial tropical moisture in deep layers with south-southwest to southwest flow in the late afternoon of 18 September (Figures 3 and 4).

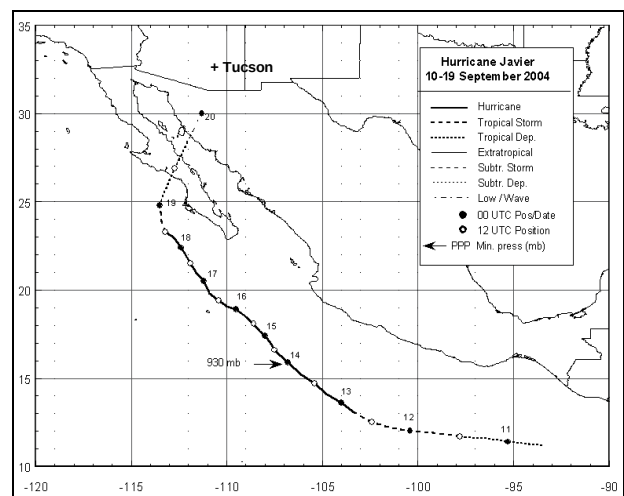


FIGURE 1. Track of Javier in September 2004 from NOAA's National Hurricane Center in Miami, Florida. The plus sign marks the location of Tucson in southern Arizona.

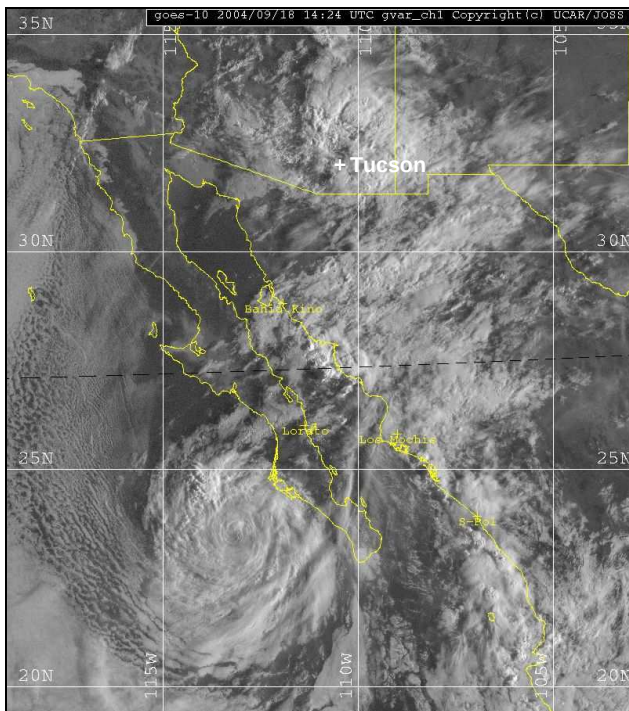


FIGURE 2. GOES-10 visible satellite image of Tropical Storm Javier at 1424 UTC/0724 MST on 18 September 2004.

3. THUNDERSTORMS AND LIGHTNING DURING THE GAME

The game began at about 2005 UTC/1305 MST on 18 September, and it was halted at 2109 UTC/1409 MST with six minutes and 13 seconds of play remaining in the second quarter. [Note: Arizona observes Mountain Standard Time throughout the year, and MST is UTC minus 7 hours.] Because of the lightning and heavy rainfall, about half of the 50,000 spectators did not return after the lightning delay. The rest waited under the stands and in nearby tents and garages. The delay lasted for 88 minutes, from 2109 to 2237 UTC/1409 to 1537 MST. This was the first time an intercollegiate football game had been halted due to lightning at the University of Arizona, although the start of a game was delayed on 11 September 1993. A total of 0.92 cm/0.37 in of rain fell at the Tucson airport on this day, making this the 4th wettest day of the summer monsoon in 2004.

3.1 Satellite imagery

The spatial pattern and movement of clouds on September 18 are shown in Figures 5 to 7. Around

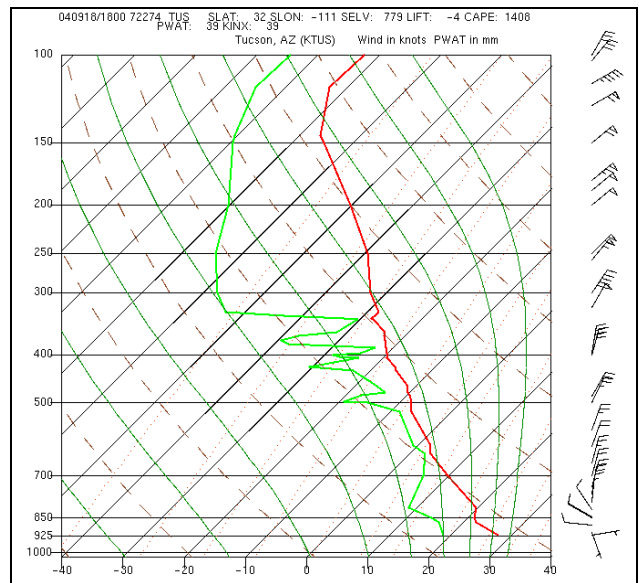


FIGURE 3. Tucson upper-air sounding at 1800 UTC/1100 MST 18 September.

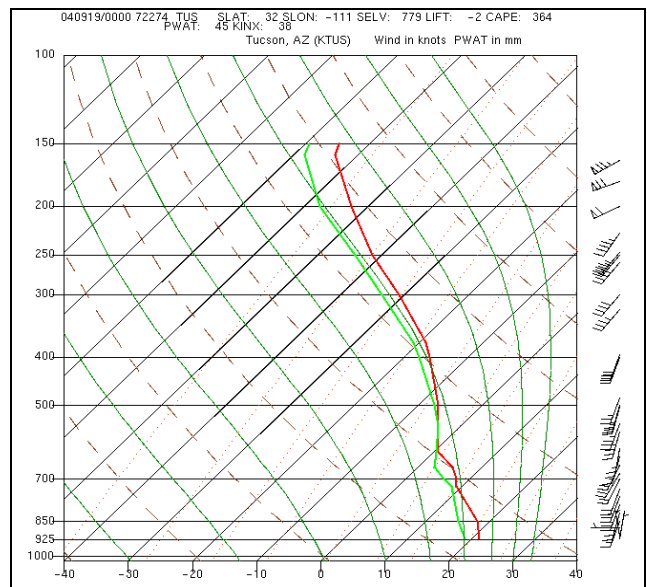


FIGURE 4. Tucson upper-air sounding at 0000 UTC 19 September/1700 MST 18 September.

noon MST (Figure 5) deep convection was beginning to develop over northern Sonora and southern Arizona. Two hours later (Figure 6), a large thunderstorm complex had formed and grown in size to the south of Tucson, and two hours after that (Figure 7), the large complex of deep convection was passing over Tucson and moving north.

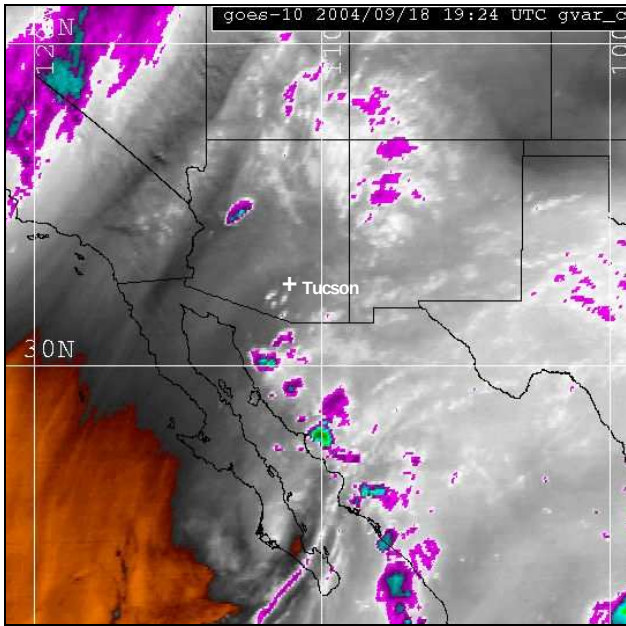


FIGURE 5. GOES-10 water vapor satellite imagery at 1924 UTC/1224 MST 18 September 2004.

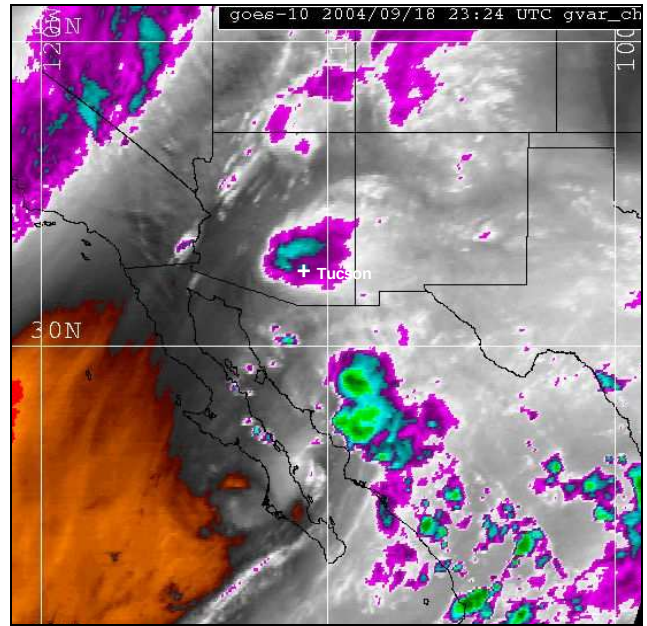


FIGURE 7. GOES-10 water vapor satellite imagery at 2324 UTC/1624 MST 18 September 2004.

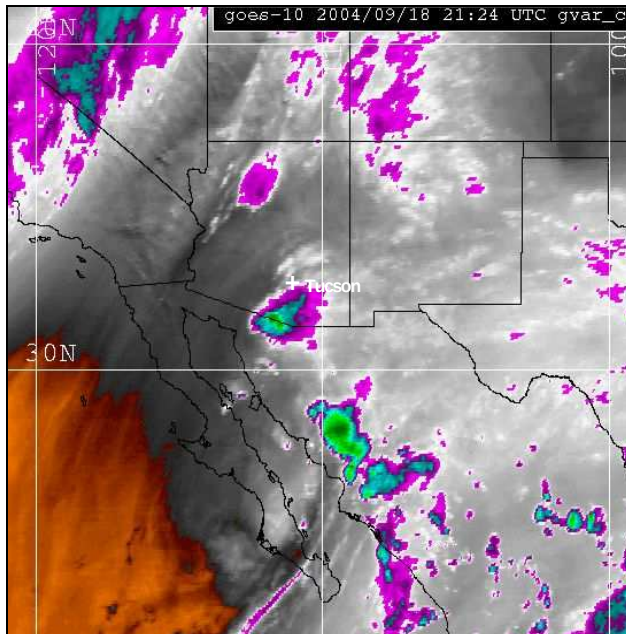


FIGURE 6. GOES-10 water vapor satellite imagery at 2124 UTC/1424 MST 18 September 2004.

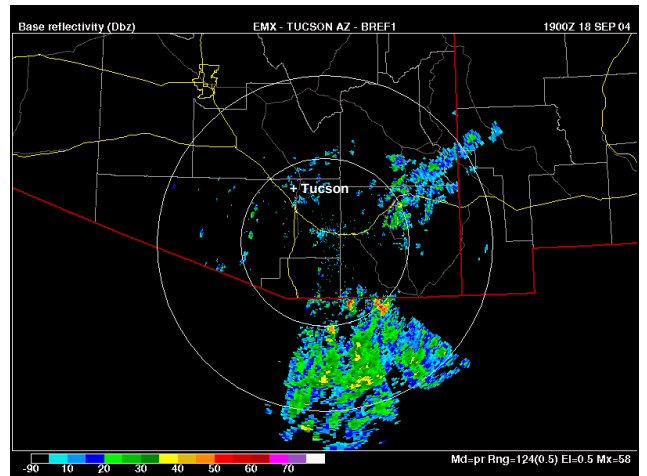


FIGURE 8. Tucson National Weather Service WSR-88D radar reflectivity at 1900 UTC/1200 MST on 18 September 2004.

3.2 Radar reflectivity

A sequence of radar images from the Tucson radar is shown in Figures 8 to 10. At 1900 UTC/1200 MST (Figure 8), the first rain showers appeared in the Tucson area and a large region to

the south. Two hours later (Figure 9), high reflectivity echoes were still present, and after another two hours (Figure 10), moderate to strong reflectivity returns continued near Tucson. The areal development over Tucson during this four-hour period was rapid. [Note: the persistent blank areas to the southwest and east-southeast in Figs. 8-10 are due to the radar beam being blocked by mountains at the 0.5-degree elevation angle.]

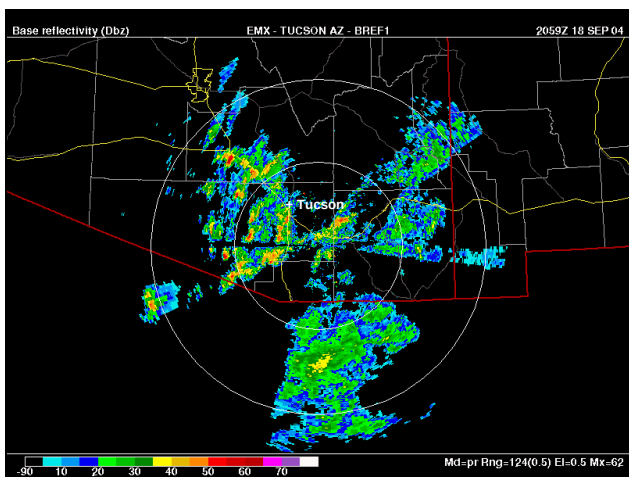


FIGURE 9. Same as Figure 8 at 2059 UTC/1359 MST.

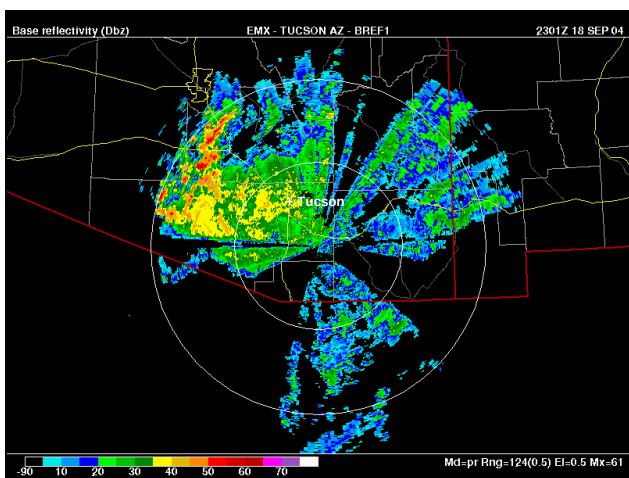


FIGURE 10. Same as Figure 8 at 2301 UTC/1601 MST.

3.3 Electric Field and Lightning

Figures 11 and 12 show the time evolution of the cloud electric field on the UA campus. This sensor was an electric field mill manufactured by Mission Instruments, Inc. (Model EFS-1000), and it was operating about 500 meters from the football stadium. The electric field (or potential gradient) provides an indication of electric charge overhead, and the records clearly show that there were highly electrified clouds near the stadium from about 2030 UTC/1330 MST to about 0030 UTC 19 September/1730 MST, in good agreement with the preceding satellite and radar views. Unfortunately, these electric field data were not available in real time in the National Weather Service (NWS) Forecast Office.

The records in Figure 11 show fair weather fields prior to 2030 UTC/1330 MST, and after that, there is

a clear polarity reversal indicative of negative charge in the clouds aloft. The first abrupt discontinuity in the field due to lightning occurred at about 2040 UTC/1340 MST, and this was caused by an intracloud discharge. The NLDN detected the first cloud-to-ground flash within 6 miles/9.6 km of the stadium at 2053 UTC/1353 MST (see below). Of particular interest here are the large undulations in the electric field toward the end of lightning activity, i.e. after 2230 UTC/1530 MST, and Figure 12 shows this end-of-storm phase in more detail.

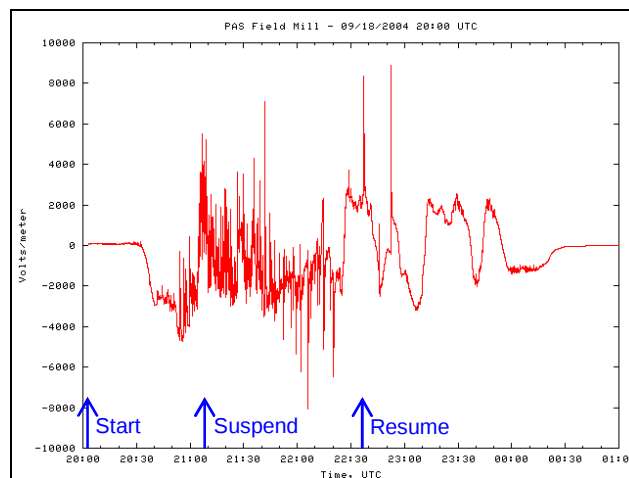


FIGURE 11. Time evolution of the electric potential gradient near the football stadium at the University of Arizona from 2000 UTC 18 September to 0100 UTC 19 September/1300 MST to 1800 MST 18 September. The abrupt vertical transitions in this record are caused by intracloud and cloud-to-ground lightning discharges. Stages of the game are shown by arrows.

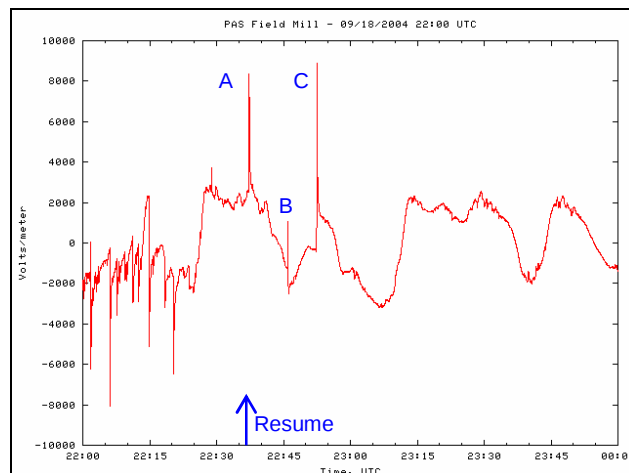


FIGURE 12. Same as Figure 11 but only for the end-of-storm phase from 2200 to 0000 UTC/1500 to 1700 MST. Letters refer to flashes after resumption of play (see text).

Maps of the CG lightning flashes detected by the NLDN are shown in Figures 13 to 15. These maps are centered on the football stadium which is marked by a star. As noted above, the high electric fields began at 2030 UTC/1330 MST, and an overview of the CG flashes that struck within 15 miles/24 km of the stadium for about 3 hours prior to the suspension of the game is given in Figure 13. Note the nearly linear progression of flashes toward the stadium from the southwest. Closer to the stadium, Figure 14 shows the CG flashes within 6 miles/9.6 km during the period prior to suspension of the game, and Figure 15 shows the flashes during the suspension. There were no flashes within 6 miles/9.6 km after the game resumed.

Table 1 shows the time development of the lightning within 15 and 6 miles/24 and 9.6 km in more detail. The largest number of CG flashes within both distances occurred during the 88 minutes when the game was suspended. After the game resumed, two CG flashes struck to the west and northwest at distances of 11.3 and 7.1 miles/18.2 and 11.3 km (not shown), beyond the range of 6 miles/9.6 km.

4. GAME DECISIONS RELATIVE TO THE LIGHTNING

The Tucson NWS Forecast Office is located 700 m from the football stadium on the University of Arizona campus. Before and during the game, UA officials spoke frequently with NWS forecasters about the weather, and during these phone calls, the main issue was the location and movement of

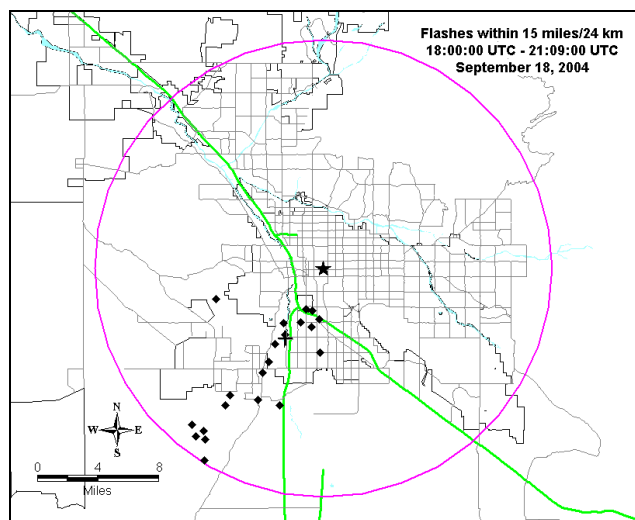


FIGURE 13. CG flashes prior to suspension of the game as detected by the NLDN within 15 miles/24 km of the stadium (star) from 1800 to 2109 UTC/1100 to 1409 MST 18 September. The plus sign indicates a positive CG flash.

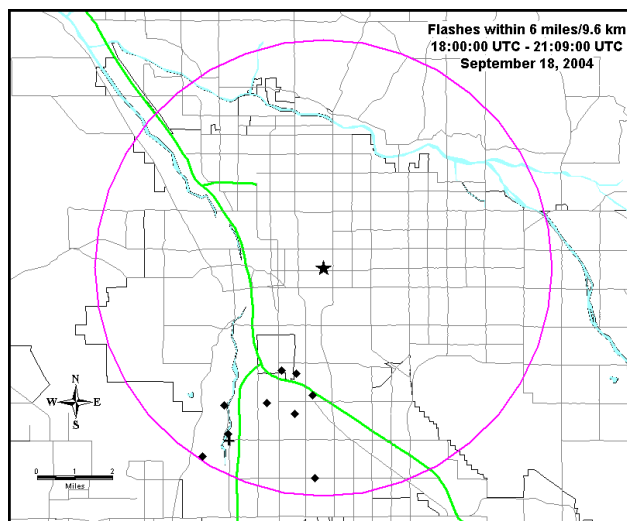


FIGURE 14. Same as Figure 13 except within a radius of 6 miles/9.6 km.

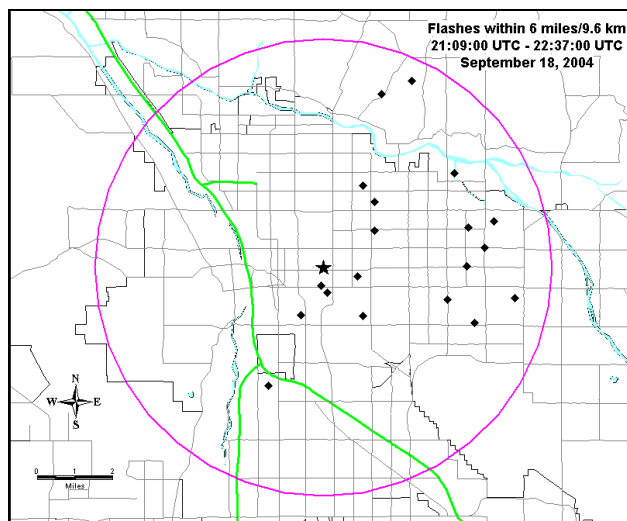


FIGURE 15. Same as Figure 13 except during the suspension of the game within a radius of 6 miles/9.6 km.

TABLE 1. Number of CG flashes detected by the NLDN in various stages of the game relative to the stadium on 18 September 2004. The number of positive CGs is in parentheses.

Stage of game UTC/MST	Distance relative to stadium	
	6 miles/9.6 km	15 miles/24 km
<u>Prior to suspension</u>		
1800-2109/1100-1409	10 (1 positive)	22 (1 pos.)
<u>During suspension</u>		
2109-2237/1409-1537	19 (0 positive)	85 (12 pos.)
<u>After suspension</u>		
2237-2359/1537-1659	0 (0 positive)	2 (0 pos.)

lightning relative to the stadium. UA staff had the final authority on decisions about the safety of the players, coaches, and spectators at the game.

In prior years, the same NWS office had provided weather information to UA staff during football games, and on 18 September, the calls were initiated by University officials. Calls were made every 10 to 15 minutes beginning about two hours before the game, based on the expected development of thunderstorms in the Tucson area during the game.

The NWS Advanced Weather Interactive Processing System (AWIPS) has the capability to overlay CG lightning locations on radar imagery and to loop these datasets. The WSR-88D radar is located 50 km southeast of Tucson. The NLDN data appear in 5-minute intervals on AWIPS, and sometimes are available before the radar and satellite data when there is a rapidly-changing situation, depending on the time sequencing of incoming data on AWIPS.

When the CG lightning came to within 10 miles (16 km) of the stadium, game officials were placed on alert, and when lightning was detected within the 6 miles/9.6 km recommended in the 30-30 rule and by the NCAA (Refs. 4,5,10,20), the game was suspended for 88 minutes.

Since play was halted late in the first half, it was decided to consider the suspension of play as half time, and all the normal halftime activities for the spectators were canceled. When play was resumed, the last 5 minutes of the second quarter were played first, followed by a short break, and then the second half was played. No phone calls were made to the NWS after the CG lightning had moved outside a range of 6 miles/9.6 km. Ultimately, the University of Wisconsin won the game by a score of 9 to 7.

5. DISCUSSION

It was stated just after the game that for the welfare and safety of the players, another lightning stoppage would probably have produced a cancellation. But in this case, no further CG lightning occurred within 6 miles/9.6 km of the stadium after resumption of the game. Football games usually continue regardless of the field conditions, except when there is lightning in the area. In contrast, baseball games are usually delayed or cancelled if there is rain or too much water on the field for safe play. Regardless of the situation, the pressure imposed by the possibility of a cancellation, and the associated loss of revenue from television and the spectators, may become so great that the lightning safety rules are not followed exactly.

In the case of this game, there were two issues related to the resumption of play. First, there was a misinterpretation of the 30-30 rule. It was thought

that the game could resume when no lightning or thunder was detected by the NLDN within 6 miles/9.6 km of the stadium. This view is not quite correct, and it is not the intent of the second 30 in the 30-30 rule. The 30-minute wait-time does not involve a distance criterion. Instead, it says that no lightning or thunder must be seen or heard for 30 minutes before resuming play, and that statement includes any type of lightning, either CG as provided by the NLDN, or a cloud discharge. In this case, game officials waited more than 30 minutes from the time of the last CG flash within 6 miles/9.6 km. The last CG within 6 miles was at 2148 UTC/1448 MST, which is 49 minutes before the game was resumed, so there was an extra 19 minutes after the 30-minute wait had expired – if the rule of 6 miles/9.6 km rule was being used.

Unfortunately, there was a large cloud discharge directly over the stadium within the first minute after resumption of play, and the NLDN detected two CG flashes at 11.3 and 7.1 miles/18.2 and 11.3 km of the stadium in the next 15 minutes. The abrupt changes in the electric field produced by these three flashes are labeled A, B, and C in Figure 12:

- The cloud flash (A) occurred at 2237 UTC/1537 MST, a time when the clouds over and near the stadium were highly electrified (see Figure 12).
- The CG flash (B) struck 11.3 miles/18.2 km to the west 9 minutes after the resumption of play.
- The last discharge (C) was a CG flash at 2252 UTC, 15 minutes after resumption of play. This flash struck 7.1 miles/11.3 km to the northwest.

High electric fields persisted near the stadium for almost two hours after the NLDN detected the last CG flash within 15 miles (Figure 11).

A second complication that became apparent in this incident is that at night when there is good visibility, lightning can frequently be seen at large distances, perhaps 50 miles/80 km or more, and clearly lightning at such large distances is not a serious threat. Alternatives to over-extending the 30 minute hold time in such situations might be to require that there be no clouds or radar echoes within a specified distance, or that there not be a high electric field at the stadium. Just how often these additional criteria would be valid, or even relevant, and/or whether a modified criterion is appropriate and under what conditions, clearly need further consideration.

We would like to point out that a lightning exposure exists in all other outdoor sporting activities, even when there are far fewer participants and spectators than football. These activities usually take place much more frequently than the six football games per season at a major university. In addition, there are lightning threats during outdoor practices, as well as in band practices, and a host of other outdoor activities. One additional benefit of

implementing the proper lightning safety procedures at football games is to increase the public awareness of lightning threats, and if the coaches, players, and spectators follow the safety guidelines, then the threat at other times and places will be minimized.

6. CONCLUSIONS

An intercollegiate football game at the University of Arizona was suspended late in the first half on 18 September 2004. The lightning was produced by thunderstorms that developed in the late morning and early afternoon as the result of deep moisture being advected northward into southern Arizona from the remnants of Tropical Storm Javier.

University officials had anticipated that lightning could be a threat during the game, and UA staff contacted the nearby National Weather Service office for updates on the location of cloud-to-ground flashes at regular intervals. When the lightning approached the stadium, an alert was issued, and then the game was suspended for 88 minutes. Spectators sought safety from the lightning and heavy rainfall under the stands and in other locations.

Shortly after play resumed, however, a cloud discharge occurred directly over the stadium, and two CG flashes were detected within 11.3 and 7.1 miles/18.2 and 11.3 km in the next 15 minutes. The presence of these flashes, and the high electric fields in the area, indicate that the resumption of play actually occurred too soon to be safe. This incident has also brought to our attention an important ambiguity in the 30-30 rule for personal lightning safety; namely, the second 30 in the 30-30 rule was interpreted to mean the time from the last *cloud-to-ground* flash within 6 miles/9.6 km, when it should have been 30 minutes after *any lightning discharge was seen or thunder was heard*, regardless of the type or range. Nevertheless, because officials at the University of Arizona had a safety plan in place and acted according to the NCAA guidelines, the suspension of this game occurred without incident.

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American Monsoon Experiment held in the southwest U.S. and Mexico during the summer of 2004. The preparation of this manuscript has been supported in part by the NASA Kennedy Space Center, Grant NAG 10-302.

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