Lightning Impacts on Sporting Event Operations

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Introduction

Lightning poses a danger to anyone who is outside. At an outdoor athletic event, that hazard exists to on-field competitors, field-preparation staff and spectators. All persons involved need as much lead time as possible to reach a safe location, but not so much as to degrade the quality of the product (i.e. sitting around waiting for the storm to arrive). We considered a study of total lightning strikes within a 10-mile radius of sports stadiums. The Earth Networks Total Lightning Network (ENTLN) was used to create a database of strikes occurring from April to October 2012.

It should be noted that those responsible for making decisions related to delays had no access to data in real-time, and thus any evaluations on their part were "judgment calls." We are reviewing the data to see if and when actions were taken; although at this time there is no known standardized policy in place for delaying games in the researched leagues.

What is Total Lightning?

Total lightning, is the combination of both intra-cloud (IC) and cloud to ground lightning (CG) strikes. ENTLN is the first lightning detection network capable of detecting a large proportion of both IC and CG lightning strikes. ENTLN contains a unique technology utilizing a broad spectrum of lightning frequencies, enabling the detection of an increased amount of lightning compared to other networks. The presence of IC lightning, even when it is not visible to a viewer on the ground, has been found to be a precursor to visible IC lightning flashes and CG lightning strikes. Additionally, an increasing ratio of IC to CG lightning has been found to be an indicator of increased probability for severe storms[1].

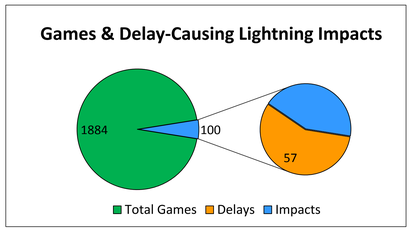

Figure 1: Lightning impacts as a percentage of the total games & delays caused by them as a percentage of the total number of delays.

Delays

A total of 1,884 games were analyzed as part of this study. Of these, 100 games saw a lightning strike within 10 miles ("impacts"), representing 5.31% of all games.

However, only 57 of these 100 lightning-impacted games were delayed. This became a topic of discussion as part of the research. (Fig. 1)

Timing of the initial lightning strikes (Fig. 2) proved to be an interesting part of the study. Many games commenced around 7 p.m. local time, immediately following the climatological diurnal peak for afternoon convection. Thus, it came as no surprise that, by far, the largest number of strikes occurred during the "pre-game" period. This was defined as the period within one hour of the scheduled game time. Impacts occurring during this period also produced a delay in 100% of the games. (Fig. 3)

The research found that once the games were underway, the initial lightning strikes were somewhat evenly spread across the course of the game, with slightly higher totals in the early part and lower totals later in the game.

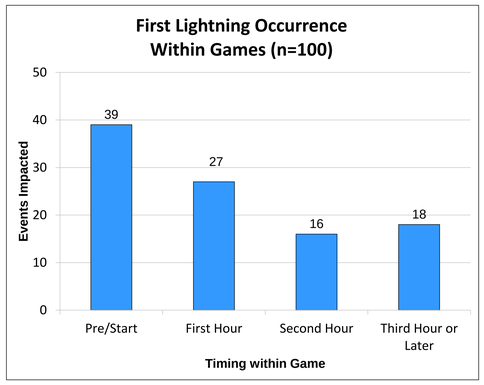

Figure 2: Initial strikes of a lightning event with each game

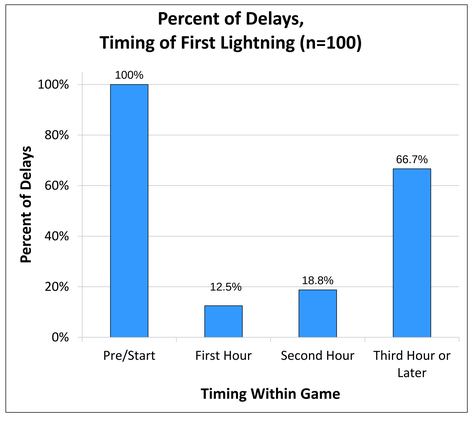

Figure 3: Percent of delays in terms of initial lightning strikes

Looking at the propensity to delay once lightning occurred, it was found that all initial strikes during pre-game led to a delay. However, this same inclination did not exist during the game-period. The research did not delve into the reasons for this; it could speculated that during the early part of the game, there seemed to be a propensity to ignore its presence in the hope that it was a solitary strike and that game operations would not need to be interrupted.

Given this disparity, there appears to be other factors in place as well. Discussions with game officials indicated that, given the presence of lightning occurring in the early minutes of game, their preference was to delay a game prior to starting, rather than once the game had begun. Primary reasons that were given were to avoid an in-game delay, and subsequent effects on players' and fans' experience.

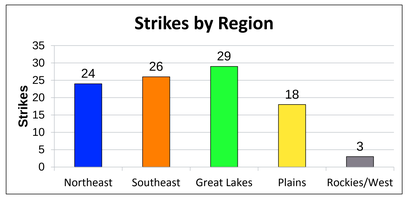

Figure 4: Lightning strikes by geographic regions

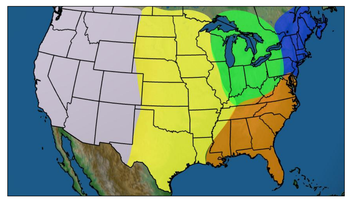

Figure 5: Geographic regions used in this study, same color scheme as Figure 4

Geography

The data are also presented in terms of geographic regions of the United States and southeastern Canada (Fig. 4, 5). Data followed summertime thunderstorm climatology. However, a marked decrease was noted across the Plains. There are some possible explanations for this, including diurnal thunderstorm patterns across the region and the presence of a season-long drought in the central U.S. during the research period.

Effects by Month

Analysis of the impacts by month (Fig. 6) showed that the data largely followed the thunderstorm patterns of the United States. All months contained a similar number of games (400-450), although due to decreased sample size, we combined the September and October data.

Impacts and lightning-related delays were at their greatest during July – the climatological convective peak in the United States. We noted that although there were actually more delays in September and October than in any other month, the number of lightning impacts were lower than any month except for April.

In general, a 1:2 delays-to-impacts ratio was noted, except for in April and August. The reason is undetermined given the small, single-season, data set.

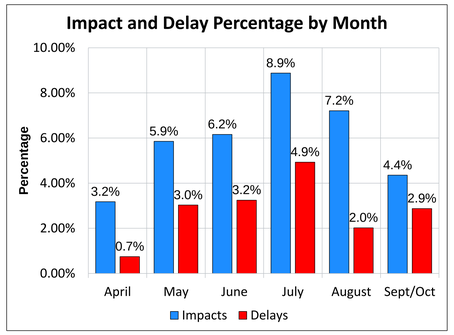

Figure 6: Lightning impact and game delay percentage broken down by month

First Strike Distance

Numerous researchers have found that thunder can be heard as far as 10 miles from a thunderstorm[2]. In a large stadium, this much audibility is not expected. Studies (NOAA) also indicate that lightning can strike 10, and sometimes as much as 25 miles from the rain source[3]. We found other athletic leagues (e.g. NCAA, ECAC) use a 10-mile standard for their delays[4].

The results of the study (Fig. 7, 8) indicate that the majority of initial lightning strikes occur at a distance of 8.5 to 10 miles from the stadium site. However, it was found that these strikes caused a delay with far less frequency than those storms which developed near the stadium. When the storms' first strikes occurred 8.5 to 10 miles from the stadium, it led to a delay in only 47% (26 of 55) of the cases *at any point* thereafter. By comparison, a 75% delay tendency was noted when the first flash was within 5 miles, and 100% of games were delayed when the initial flash was within 2 miles of a stadium.

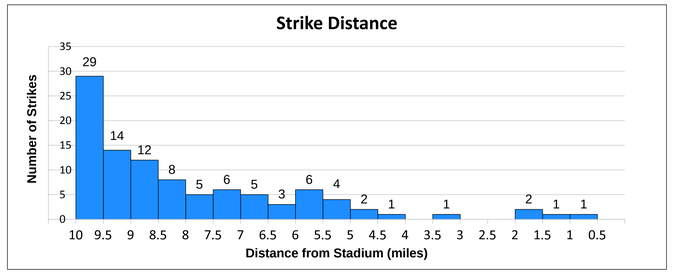

Figure 7: Count of initial lightning strike distances, measured from the stadium site

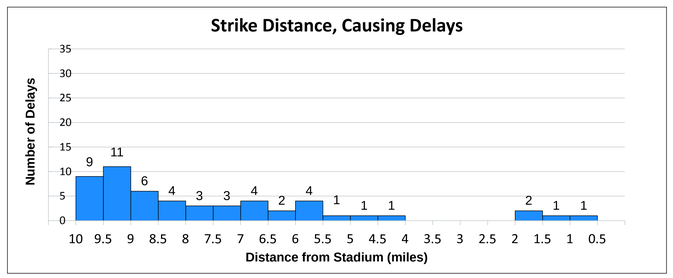

Figure 8: Count of initial lightning strike distances, measured from the stadium site, as determined to cause delays to the game

Indoor vs. Outdoor

We did a comparison of the number of games impacted by lightning at outdoor facilities with those in an indoor facility. Of course, the number of operational impacts at these covered stadiums was zero, so we considered lightning impacts to the stadium site. There has been a trend within the United States to construct stadiums that contain retractable roofs, allowing for open-air competition when the weather is cooperative, but still having the ability to play when inclement weather strikes. The down-side to having "the best of both worlds" is financial cost, as design and construction of the stadium with a roof is more expensive than an open-air stadium. While we did not consider the financial aspect – both construction and game operations – the question, "Is a dome/roof worth it?" was posed.

The research (Fig. 9) indicated that during the mid-to-late summer, those sites with a roof saw more than a 100% increase in lightning compared to their outdoor counterparts. However, it should be noted that three of these stadiums are located in the Southeast, where spring- and summertime thunderstorms are near-daily occurrence. Since there are no delays in these indoor stadiums, the game is not interrupted due to lightning. Fan satisfaction would also be expected to improve, as the variable to game length presented by lightning is removed from these games, making the only determining factor for game length the product on the field. However, we did not consider what percentage of delays would be considered a break-even point, financially, for roof construction.

In the early and late months of the season, when lightning strikes are less numerous nationwide, the advantage provided by the indoor stadiums is diminished. The notable outlier within the data, June, would likely be smoothed given a multiple-year study. In general, the statistics seem to indicate that a cost/benefit analysis was completed by builders.

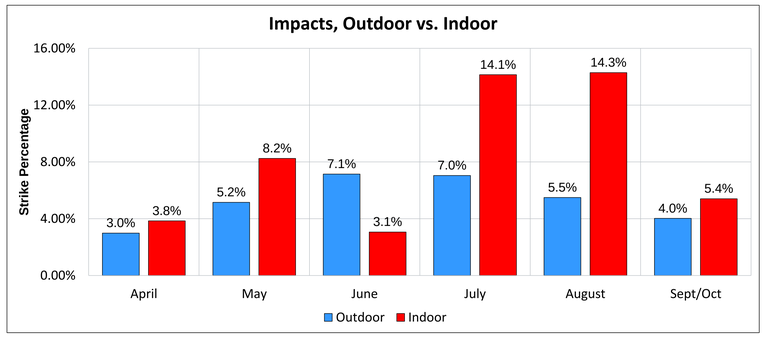

Figure 9: Lightning strike impacts, as a percentage of total games attempted at both outdoor (no roof) or indoor (retractable/permanent roof) facilities

Conclusion

- The study showed that the lack of a standardized policy for event delays due to lightning was problematic. By not having a standard, the decision to delay became a judgment call, and as a result, it created potentially dangerous situations. A 14% delay-rate in the early portion of the event indicates officials often tried to avoid stopping games, jeopardizing fan and player safety. To an outside observer, this could give the perception that events are unsafe during severe or changing weather conditions.
- Timing of delays may have financial and operational implications that could play into the decision whether or not to delay. When lightning occurred early in the event, the propensity seemed to be to ignore its presence in the hope that it was a solitary strike and that event operations would not need to be interrupted.
- The desire to reach the events' half-way point could impact the decision. Often, events are often considered "official" once 50% of the event is completed. An unofficial event would negate all event statistics and create the need to reschedule the event even if just barely shy of the required half-way point. In this situation, box office receipts would also likely need to be refunded to customers. By contrast, once the event has passed the halfway point, it is considered as if a full-event had been played even if it does not reach completion: statistics are accepted and refunds are not required. Thus, officials may feel pressured to ensure the event reaches its mid-point, even if this puts game quality and player safety at risk.
- Lightning distance from the stadium could also lead to the perception of danger during a thunderstorm. Although all first strikes within 2 miles were found to cause a delay, the resulting delay-rate was only 50% on strikes 2 to 5 miles away, even though an initial strike at this distance could be equally as dangerous as the near-stadium strikes.
- The results of the geographic breakdown of lightning impacts went somewhat against the common-sense results anticipated. While we anticipated large numbers of impacts at Southeastern U.S. locations, we did not expect equivalent results across the U.S. Northern Tier. These results underscore the need to create a lightning standard, regardless of location.
- We found there was a wide array of outcomes as a result of officials delaying events on the basis of judgment calls, and not necessarily using lightning data or even radar data. While future research would be required to create these standards, it is evident that standards are needed to assure the safety of all involved.

Opportunities for future research

- Determine if a distance other than 10 miles would provide better warning
- Would a different initial strike distance be needed depending of stadium size?
- Follow the storm after the initial lightning, to see whether it moved over the stadium site
- Expansion of the timing aspect of the study. Would see a reduction in delays starting games at a different time?
- Consider societal impacts of standardized delays on players and spectators from youth leagues to the professional level

[1]Darden CB, Nadler DJ, Carcione BC, Blakeslee RJ, Stano, GT, and Buechler, DE. Utilizing total lightning information to diagnose convective trends. Bulletin of the American Meteorological Society, 2010; 91: 167–175.

[2]"Flash Facts About Lightning." *National Geographic*. National Geographic Society, 25 June 2005. Web. 12 Dec. 2012. <http://news.nationalgeographic.com/news/2004/06/0623_040623_lightningfacts_2.html>.

[3]"Bolts from the Blue." *NWS Lightning Safety Outdoors*. National Weather Service, n.d. Web. <http://www.lightningsafety.noaa.gov/bolt_blue.htm>.

[4]Walsh KM, Hanley MJ, Graner SJ, Beam D, Bazluki J. A survey of lightning policy in selected division I colleges. J Athl Train. 1997 Jul;32(3):206–210