LIGHTNING SAFETY AT AIRPORTS – MATERIAL FOR THUNDER

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ABSTRACT

Airport employees and airline ramp operators working outdoors are routinely exposed to lightning hazards during the spring and summer months. As a safety precaution airline and airport operators alert their personnel of an imminent lightning risk. Typically operators have personnel seek shelter indoors when the first lightning strike occurs within a predefined distance of the airport. After a period of waiting inside without any further lightning nearby, operators may decide to resume ramp operations again. However, there is substantial ambiguity involved in that decision-making process caused by differing lightning safety rules employed and by the variety of sources of lightning information commercially available. Discussion of these ambiguities is the focal point of this paper.

1. INTRODUCTION

Thunderstorms and lightning pose a safety risk to personnel working outdoors, such as people maintaining airport grounds (e.g., mowing grass or repairing runway lighting) or servicing aircraft on ramps (handling baggage, food service, refueling, tugging and guiding aircraft from/to gates, etc.). Since lightning strikes can cause serious injuries or death, it is important to provide timely alerts to airport personnel so that they can get to safety when lightning is imminent.

There are no standardized lightning safety rules employed across the aviation industry, which may yield notably different rules being applied by multiple airlines even at a single airport. The rules employed by airlines to halt ramp operations, and airport operators to get outdoor personnel inside, are typically based on a *first lightning strike* observed within a critical distance of the airport, but there is variety in the distance criteria employed by the airlines and airport operators, and there can be a variety of different sources of lightning information. There are likewise differences among operators in how long one should wait after the last lightning strike occurred until outdoor activities may safely resume. Moreover, ramp closures slow down airport operations and, if they are of unnecessarily prolonged duration, may cause avoidable inefficiencies not just for terminal operations but potentially also for traffic management of the national airspace.

Hereafter we discuss some of the key issues related to these lightning safety rules. From an airline operator's perspective this is an optimization problem in terms of maximizing both efficiency (i.e., minimizing downtimes) and safety for ground personnel (minimizing injuries). While there are significant economic impacts in these decisions, including operational downtime and personnel injuries, our focus will be on highlighting a number of the key ambiguities involved in the decision-making process.

2. LIGHTNING AND ITS DETECTION

There is substantial observational, laboratory and modeling evidence that strong updrafts in the mixed phase region are conducive to cloud electrification and the buildup of strong

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electric fields and lightning [e.g., Workman and Reynolds 1949; Williams and Lhermitte 1983; Dye et al. 1989; Zipser and Lutz 1994; Saunders and Peck 1998; Takahashi and Miyawaki 2002; Mansell et al. 2005; Deierling et al. 2008; Deierling and Petersen 2008].

Lightning is generally divided into "*Cloud-to-Ground*" (CG) and "*In-Cloud*" (IC) lightning. CG lightning is defined as lightning that strikes the ground, while IC lightning is defined here as lightning that occurs within clouds, between clouds, or between clouds and clear air. A CG lightning flash may be composed of several (typically 2 – 4, but sometimes as many as 20) strokes that are separated in time by 20 – 100 msec [Cummins and Murphy 2009] and in space by up to 12 km [Valine and Krider 2002].

Although only CG lightning causes direct injuries to airport personnel and equipment, it is also important to monitor IC lightning since severe storms can produce significantly more IC flashes than CG flashes [e.g., Williams et al. 1999; Boccippio et al. 2001]. Thus, for nowcasting and warning applications, total (IC and CG) lightning is a better indicator of storm growth and intensity than CG lightning by itself. In addition, the buildup of IC lightning typically precedes CG lightning in a growing thunderstorm by several minutes [MacGorman et al. 2011]. This means that IC lightning detection has the potential to provide an advance warning of CG strikes, especially when thunderstorms develop overhead [Cummins and Murphy 2009].

Current lightning detection systems provide real-time lightning information based on ground-based sensors that use magnetic direction finders, time of arrival techniques, VHF interferometry, or a combination of these techniques [Cummins and Murphy 2009]. Generally such detection systems consist of multiple receiver stations detecting the electromagnetic radiation emitted from lightning flashes.

Lightning emits electromagnetic radiation over a wide range of frequencies from the Very Low Frequency (VLF) / Low Frequency (LF) to Very High Frequency (VHF) / Ultra High Frequency (UHF) range. Different portions of a lightning discharge radiate at a spectrum of frequencies; for example, return strokes of CG flashes radiate strongly at VLF/LF whereas other parts of IC and CG lightning discharges, such as negative leaders, dart leaders, etc. emit strongly at VHF [Shao et al. 1999; Thomas et al. 2001]. Generally, VLF and LF frequency radiation can be measured over much longer distances than VHF radiation.

Long-range lightning detection systems detect lightning at the VLF frequency range. While they can provide global CG coverage, their detection efficiency is lower than shorter range networks that operate at higher frequencies. The LF networks, for example, detect CG lightning activity with high detection efficiencies and can also detect nearby IC lightning activity. VHF lightning detection systems detect both IC and CG lightning with very high detection efficiencies within a 100 – 200 km range.

3. AMBIGUITIES WITH SAFETY RULES

The most important ambiguities of lightning safety rules utilized at airports are related to the *sources of lightning observation* and the *procedures in place* by operators.

Today's airline ground operators are typically reacting to a lightning strike in the vicinity of an airport and then wait until it is deemed safe to resume work outside again [e.g., Airport Cooperative Research Program (ACRP) Report #8 2008]. The former involves setting a critical *threshold distance* that is used to close the ramp if a first lightning strike occurs within that range, while the latter is based on a critical *waiting period* after the last lightning strike within that threshold distance. Some operators may use multiple thresholds to increasingly scale back outdoor operations until finally pulling people inside to safety if lightning occurs too close. In addition to lightning information, operators also use radar and satellite observations to guide their decisions to close a ramp for operations when it may no longer be safe for people to work outdoors [e.g., Johnson et al. 2009]. A perhaps "typical" guideline is based on a critical threshold distance of 6 miles and a 30-min waiting period after the last lightning strike [ACRP 2008]. We refer to this as Rule #1. Another operator rule (Rule #2, in our study) is based on a 5-mile radius and 15-min waiting period, while Rule #3 is based on a 3-mile radius and a 6-min wait after the last lightning strike before resuming outdoor work again.

The uncertainty associated with lightning information is related to what part(s) of the electromagnetic spectrum may be measured by a sensor, the detection efficiency of a sensor network, the algorithm used to classify a lightning source as either IC or CG, and the accuracy of the location algorithm.

We have found clear differences between the type, location and number of lightning detected among available networks. Figure 1, for example, shows the lightning frequency per minute measured by three networks for about an hour within a 5-mile radius around an airport. This is a fairly typical distance that is used by airlines to employ ramp closures. While the total lightning information is somewhat similar, there are very clear differences in the IC and CG portion of that information.

The combination of different lightning safety rules with different sources of lightning information provides a sense of the overall ambiguities associated with ensuring safe yet efficient airport ramp operations. Figure 2 shows the cumulative distribution of ramp closures as a result of using various combinations of lightning safety rules and lightning information from lightning networks operating at LF frequencies. A reduction of the critical threshold distance and waiting period after the last lightning strike yields notably more numerous yet shorter ramp closures and a significantly reduced overall downtime for airline operations. However, such an approach may come with increased safety risks and possibly added inefficiency due the time it takes to go inside to safety and then resume work again. The ambiguity due to a choice in source of lightning information is substantial, but its impact on the overall downtime is typically smaller than that resulting from the selection of a critical threshold distance and wait time before resuming ramp operations again after the last lightning strike.

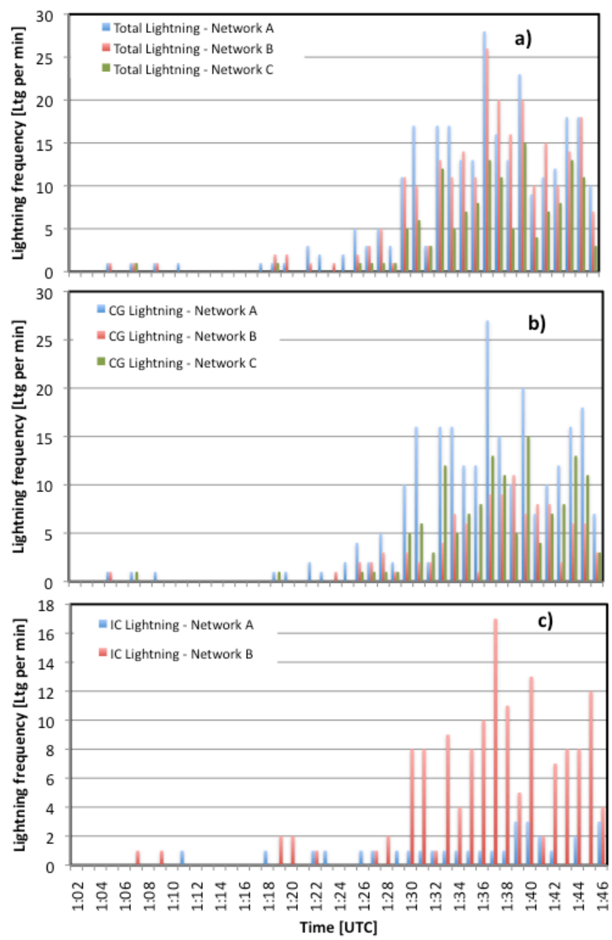

Figure 1. Lightning information provided by three different sources. The total lightning is shown in the top panel, while IC and CG information is provided in the middle and bottom panels, respectively.

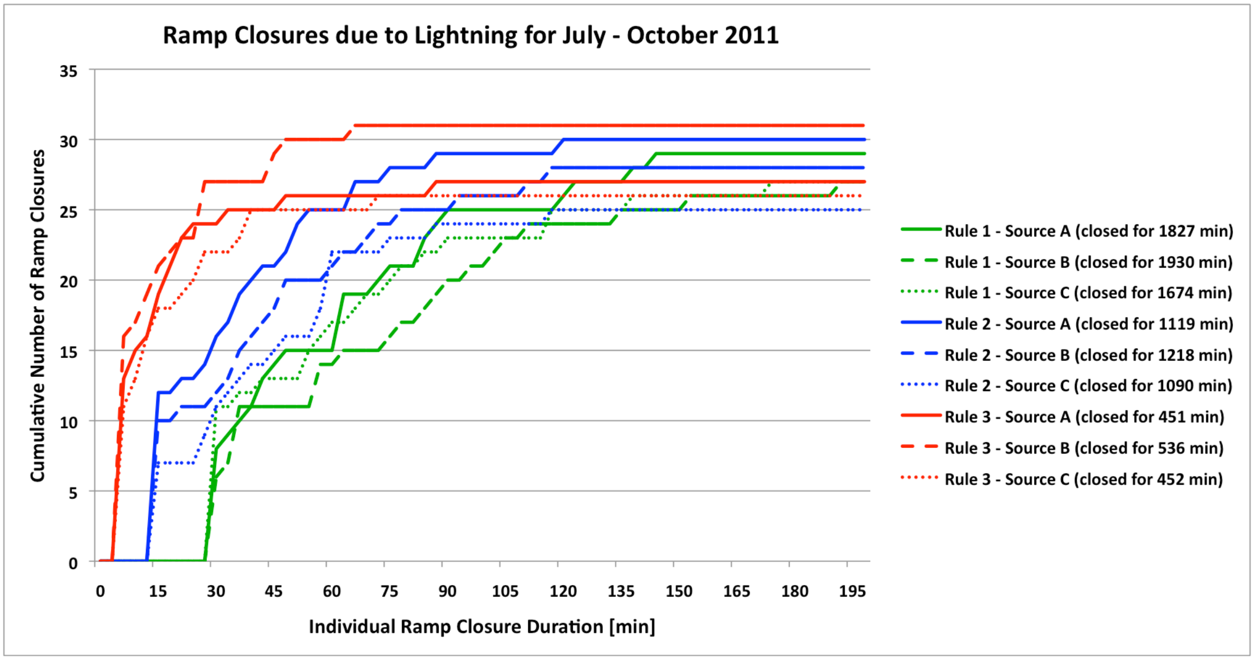

Figure 2. Ramp closures due to lightning threat near Airport X. Shown are the cumulative ramp closure distributions based on three different operator safety rules and three sources of lightning information. The total ramp closure duration for each combination is listed in parenthesis as well.

4. OUTLOOK

The overarching goal of this effort is to identify potential inefficiencies in airport operations in response to lightning hazards (e.g., closing a ramp too soon or for too long) or possible safety risks for ground personnel (e.g., closing ramp too late or reopen too early).

Our research makes use of a variety of LF and VHF sources of lightning information and benefits from a close collaboration with a number of aviation operators.

We envision that our analyses and results will provide a useful basis for operators to better appreciate the notable ambiguities involved in lightning monitoring and issuing alerts, and ultimately make effective use of the available information.

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