Updated Recommendations for Lightning Safety—1998

Ronald L. Holle,* Raúl E. López,* and Christoph Zimmermann+

1. Introduction

Meteorological agencies in the United States and around the world issue warnings, statements, and other forecasts with the goal of mitigating casualties and damages caused by severe weather. These products are issued for three of the four important causes of storm-related fatalities: floods, tornadoes, and hurricanes (Fig. 1). However, no warnings or forecasts are typically issued for lightning, which is reported by the National Oceanic and Atmospheric Administration (NOAA) publication *Storm Data* to rank second to floods in the number of deaths. Lightning also injures at least 300 people each year in the United States. After taking into account the underreporting of lightning deaths and injuries (López et al. 1993), about 100 people are estimated to be killed and more than 500 injured by lightning annually in the United States. Cherington et al. (1999) found that when emergency room visits were included, a ratio of 10 lightning injuries to one death applied in Colorado.

The magnitude of the cloud-to-ground lightning hazard is understood better today than had been the case due in large part to data collected by the U.S. National Lightning Detection Network (NLDN) described by Holle and López (1994) and Cummins et al. (1998). From 1992 to 1995, the NLDN identified an average of 21 746 000 cloud-to-ground flashes per year (Orville and Silver 1997). Lightning occurs in the United States every day in summer and nearly every day during the rest of the year. Since lightning strikes the ground with such great frequency and is so widespread, it is not possible to warn each person for every flash. *For this reason, lightning can be considered the most dangerous weather hazard that many people encounter each year.* Lightning-specific warnings have proven effective in some unique applications, such as at the Kennedy Space Center and during major golf tournaments.

Although the scientific understanding of lightning has advanced significantly in the last few decades (Krider 1996), a consistent match between basic science and applications to safety had not been made. For example, NOAA (1994) said to squat on the balls of your feet and minimize contact with the ground, while NOAA (1985) recommended dropping to the knees during the lightning threat, and NOAA (1970) suggested dropping to the ground. Concerning when to reach a safe location, NOAA (1994) recommended going to a safe location at the first sound of thunder, NOAA (1985) was not specific about when to go to a safe place, and NOAA (1970) made no mention of this decision process. Similar variations can be found in these and many other publications regarding additional issues such as medical and first aid approaches to lightning victims.

In response to inconsistent safety recommendations and recent findings concerning the lightning phenomenon, a Lightning Safety Group (LSG) met informally during the American Meteorological Society's (AMS) Annual Meeting in Phoenix, Arizona, in January 1998. The LSG was composed of people who were known to be active in lightning safety and education issues, but the list was by no means complete. Attendees were involved in developing warning methods, giving lightning safety presentations to groups, seeing patients who were lightning casualties, conducting research into the epidemiology of lightning victims, and/or developing policies for lightning safety. Individuals who were able to attend

*NOAA/National Severe Storms Laboratory, Norman, Oklahoma.
+Global Atmospherics, Inc., Tucson, Arizona.
Corresponding author address: Ronald L. Holle, National Severe Storms Laboratory, NOAA, 1313 Halley Circle, Norman, OK 73069.
E-mail: holle@nssl.noaa.gov
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the meeting are listed in Table 1. Also included are people who are active in these lightning safety and education issues but were unable to attend.

The following summarizes recommendations adopted during the AMS Annual Meeting and in subsequent drafts circulated from January to May 1998. The LSG internally agreed upon this text during the process, but it was not reviewed externally. Only the references were added to the following consensus text. The recommendations are being circulated now for general information and to stimulate further comments and discussion from readers of the *Bulletin.*

2. The recommendations

a. Abstract

On average, lightning causes more casualties annually in the United States than any other storm-related phenomena, except floods (López et al. 1993; Curran et al. 1997; Holle and López 1998). Many people incur injuries or are killed due to misinformation and inappropriate behavior during thunderstorms (Howard and Holle 1995; Howard et al. 1998). A few simple precautions can reduce many of the dangers posed by lightning (Bennett et al. 1997). In order to standardize recommended actions during thunderstorms, a group of qualified experts from various backgrounds collectively have addressed personal safety in regard to lightning, based on recently improved understanding of thunderstorm behavior. This Lightning Safety Group first convened during the 1998 American Meteorological Society Annual Meeting in Phoenix, Arizona, to outline appropriate actions under various circumstances when lightning threatens.

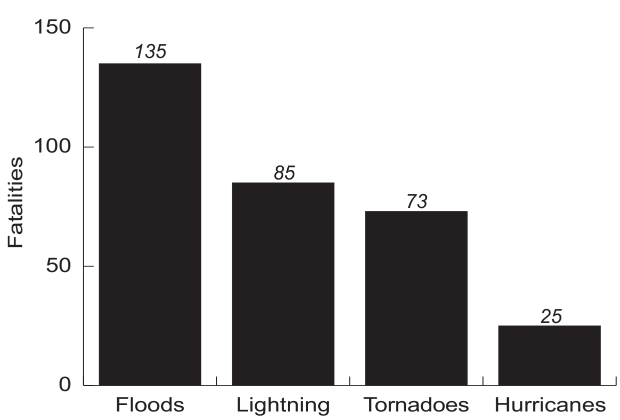

FIG. 1. Annual number of storm-related deaths in the United States from 1966 to 1995 (from *Storm Data*).

b. Key conclusions

The seemingly random nature of thunderstorms cannot guarantee the individual or group absolute protection from lightning strikes; however, being aware of and following proven lightning safety guidelines can greatly reduce the risk of injury or death. Individuals are ultimately responsible for their personal safety and have the right to take appropriate action when threatened by lightning (Bennett et al. 1997). Adults must take responsibility for the safety of children in their care during thunderstorm activity.

c. Safer locations during thunderstorms and locations to avoid

- No place is absolutely safe from the lightning threat; however, some places are safer than others (Howard and Holle 1995; Howard et al. 1998).
- Large enclosed structures (substantially constructed buildings) tend to be much safer than smaller or open structures. The risk for lightning injury depends on whether the structure incorporates lightning protection, construction materials used, and the size of the structure (National Fire Protection Association 1997a,b).
- In general, fully enclosed metal vehicles such as cars, trucks, buses, vans, fully enclosed farm vehicles, etc., with the windows rolled up provide good shelter from lightning. Avoid contact with metal or conducting surfaces outside or inside the vehicle.
- *Avoid* being in or near high places and open fields, isolated trees, unprotected gazebos, rain or picnic shelters, baseball dugouts, communications towers, flagpoles, light poles, bleachers (metal or wood), metal fences, convertibles, golf carts, and water (ocean, lakes, swimming pools, rivers, etc.).
- When inside a building *avoid* use of the telephone, taking a shower, washing your hands, doing dishes, or any contact with conductive surfaces with exposure to the outside such as metal door or window frames, electrical wiring, telephone wiring, cable TV wiring, plumbing, etc.

d. Safety guidelines for individuals

- Generally speaking, if individuals can see lightning and/or hear thunder they are already at risk. Louder or more frequent thunder indicates that lightning activity is approaching, increasing the risk for lightning injury or death. If the time delay between seeing the flash (lightning) and hearing the bang (thunder) is less than 30 seconds, the individual

TABLE 1. Participants in the Lightning Safety Group meeting in Phoenix, Arizona, January 1998, and active collaborators.

Affiliation	Location	Discipline	Participant
College of William and Mary	Williamsburg, VA	Athletic trainer	B. Bennett
Lightning Protection Technology	Tucson, AZ	Engineer	L. Byerley
University of Illinois, Chicago	Chicago, IL	Emergency physician	M. A. Cooper
Global Atmospherics, Inc.	Tucson, AZ	Engineer	K. L. Cummins
National Severe Storms Laboratory	Norman, OK	Research meteorologist	R. L. Holle
National Severe Storms Laboratory	Norman, OK	Research meteorologist	K. W. Howard
National Lightning Safety Institute	Louisville, CO	Engineer, president	R. Kithil
The University of Arizona	Tucson, AZ	Professor	E. P. Krider
Global Atmospherics, Inc.	Tucson, AZ	Product manager	L. C. Lawry
National Severe Storms Laboratory	Norman, OK	Research meteorologist	R. E. López
St. Paul Fire and Marine Insurance Co.	St. Paul, MN	Loss control specialist	B. Lunning
NASA/Kennedy Space Center	Florida	Manager	J. T. Madura
Quality Protection Systems, Inc.	Rochester, NY	Engineer, president	M. McGee
U.S. Air Force	Patrick AFB, FL	Meteorologist	W. P. Roeder
Eggers Middle School	Hammond, IN	Science teacher	J. Vavrek
Global Atmospherics, Inc.	Tucson, AZ	Safety management	C. Zimmermann
Collaborators not at meeting			
Indooroopilly Medical Centre	Chapel Hill, Australia	Medical doctor, engineer	C. Andrews
Colorado Lightning Data Center	Denver, CO	Physician	M. Cherington
Anubis & Bastet Productions	Tucson, AZ	Writer	G. Harwood
Electricité de France	Paris, France	Physician	É. Gourbière
Eastern Michigan University	Ypsilanti, MI	Geography professor	C. Ojala
The Chicago Medical School	North Chicago, IL	Psychology professor	M. Primeau
East Carolina University	Greenville, NC	Sports medicine physician	K. M. Walsh

should be in, or seek, a safer location (see section 2c above). Be aware that this method of ranging has severe limitations in part due to the difficulty of associating the proper thunder to the corresponding flash.

- High winds, rainfall, and cloud cover often act as precursors to actual cloud-to-ground strikes, and should motivate individuals to take action. Many lightning casualties occur in the beginning, as the storm approaches, because people ignore these precursors (Holle et al. 1993). Also, many lightning casualties occur after the perceived threat has passed (Holle et al. 1993). Generally, the lightning threat diminishes with time after the last sound of thunder but may persist for more than 30 minutes. When thunderstorms are in the area but not overhead, the lightning threat can exist even when it is sunny, not raining, or when clear sky is visible (Holle et al. 1993).
- When available, pay attention to weather warning devices such as NOAA weather radio and/or credible lightning detection systems; however, do not let this information override good common sense.

e. Considerations for small groups and/or when the evacuation time is less than 10 minutes

- An action plan must be known in advance by all persons involved (see section 2g). School teachers, camp counselors, lifeguards, and other adults must take responsibility for the safety of children in their care (Bennett et al. 1997).
- Local weather forecasts, NOAA weather radio, or the Weather Channel should be monitored prior to the outdoor event to ascertain if thunderstorms are in the forecast. Designate a responsible person to monitor forecasted weather as well as to observe on-site developments to keep everyone informed when potential threats develop.
- Recognize that personal observation of lightning may not be sufficient; additional information such as a lightning detection system or additional weather information may be required to ensure consistency, accuracy, and adequate advance warning.
- Even though technology and instrumentation have proven to be effective, they cannot guarantee safety. Instrumentation can be used to enhance warning during the initial stages of the storm by detecting lightning in relation to the area of concern. Advance notification of the storm's arrival should be used to provide additional time to seek safety. Detectors are also a valuable tool to determine the "all clear" (last occurrence of lightning within a specified range), providing a time reference for safe resumption of activities.

f. Safety guidelines for large groups and/or when the evacuation time is more than 10 minutes

- An action plan must be known in advance by all persons involved (see section 2g). Adults must take responsibility for the safety of children in their care.
- Local weather forecasts, NOAA weather radio, or the Weather Channel should be monitored prior to the outdoor event to ascertain if thunderstorms are in the forecast. During the event, a designated responsible person should monitor site relative weather condition changes.
- Personal observation of the lightning threat is not adequate; additional information including detecting actual lightning strikes and monitoring the range at which they are occurring relative to the activity is required to ensure consistency, accuracy, and adequate advance warning.
- Technology and instrumentation, while often effective, cannot guarantee safety. Instrumentation can be used to enhance warning during the initial stages of the storm by detecting lightning in relation to the area of concern. Advance notification of the storm's arrival should be used to provide additional time to seek safety. Detectors are also a valuable tool to determine the all clear (last occurrence of lightning within a specified range), providing a time reference for safe resumption of activities.
- When larger groups are involved the time needed to properly evacuate an area increases. As time requirements change, the distance at which lightning is noted and considered a threat to move into the area must be increased. Extending the range used to determine threat potential also increases the chance that a localized cell or thunderstorm may not reach the area, giving the impression of a false alarm.
- Remember, lightning is always generated and connected to a thundercloud but may strike many miles from the edge of the thunderstorm cell. Acceptable downtime (time of alert state) has to be balanced with the risk posed by lightning. Accepting responsibility for larger groups of people requires more sophistication and diligence to assure that all possibilities are considered.

g. Important components of an action plan

- Management, event coordinators, organizations, and groups should designate a responsible person(s) to monitor the weather to initiate the evacuation process when appropriate. Monitoring should begin hours and even days ahead of an event (Holle et al. 1995).

- A protocol needs to be in place to notify all persons at risk from the lightning threat. Depending on the number of individuals involved, a team of people may be needed to coordinate the evacuation plan. Adults must take responsibility for the safety of children in their care.
- Safer sites must be identified beforehand, along with a means to route the people to those locations. School buses are an excellent lightning shelter that can be provided (strategically placed around various locations) by organizers of outdoor events, with larger groups of people and larger areas, such as golf tournaments, summer day camps, swim meets, military training, scout groups, etc. (Bennett et al. 1997; Walsh et al. 1997).
- The all clear signal must be identified and should be considerably different from the warning signal.
- The action plan must be periodically reviewed by all personnel and drills conducted.
- Consider placing lightning safety tips and/or the action plan in game programs, flyers, score cards, etc., and placing lightning safety placards around the area. Lightning warning signs are effective means of communicating the lightning threat to the general public and raise awareness (Bennett et al. 1997).

h. First aid recommendations for lightning victims

Most lightning victims can actually survive their encounter with lightning, especially with timely medical treatment (Andrews et al. 1992; Cooper 1995; Cooper and Andrews 1995). Individuals struck by lightning do not carry a charge and it is safe to touch them to render medical treatment. Follow these steps to try to save the life of a lightning victim.

1) First

Call 911 to provide directions and information about the likely number of victims.

2) Response

The first tenet of emergency care is "make no more casualties." If the area where the victim is located is a high risk area (mountain top, isolated tree, open field, etc.) with a continuing thunderstorm, the rescuers may be placing themselves in significant danger.

3) Evacuation

It is relatively unusual for victims who survive a lightning strike to have major fractures that would cause paralysis or major bleeding complications unless they have suffered a fall or been thrown a distance. As a result, in an active thunderstorm, the rescuer needs to choose whether evacuation from very high risk areas to an area of lesser risk is warranted and should not be afraid to move the victim rapidly if necessary. Rescuers are cautioned to minimize their exposure to lightning as much as possible.

4) Resuscitation

If the victim is not breathing, start mouth to mouth resuscitation. If it is decided to move the victim, give a few quick breaths prior to movement. Determine if the victim has a pulse by checking the pulse at the carotid artery (side of the neck) or femoral artery (groin) for at least 20–30 seconds. If no pulse is detected, start cardiac compressions as well. In situations that are cold and wet, putting a protective layer between the victim and the ground may decrease the hypothermia that the victim suffers, which can further complicate the resuscitation. In wilderness areas and those far from medical care, prolonged basic CPR is of little use: the victim is unlikely to recover if they do not respond within the first few minutes. If the pulse returns, the rescuer should continue ventilation with rescue breathing if needed for as long as practical in a wilderness situation. However, if a pulse does not return after 20–30 minutes of good effort, the rescuer should not feel guilty about stopping resuscitation.

i. Conclusions

Avoid unnecessary exposure to the lightning threat during thunderstorm activity. Follow these safety recommendations to reduce the overall number of lightning casualties. An individual ultimately must take responsibility for his or her own safety and should take appropriate action when threatened by lightning. School teachers, camp counselors, coaches, lifeguards, and other adults must take responsibility for the safety of children in their care. A weather radio and the use of lightning detection data in conjunction with an action plan are prudent components of a lightning warning policy, especially when larger groups and/or longer evacuation times are involved.

3. Discussion and summary

A major result of this meeting was a general agreement concerning the "30–30 rule." The first 30 refers to the number of seconds between "flash" and "bang" that initiates safety precautions. The second 30 refers to the number of minutes after the last flash or thunder in order to establish an all clear signal. Research showing that the average distance between successive flashes is roughly two to three miles (Krider 1988) was used in prior safety recommendations (Vavrek et al. 1993; Holle et al. 1995). But López and Holle (1999) found this distance to be greater in larger and more organized storms. It was also noted that beyond about 30 seconds (10 km or 6 miles), lightning is not perceived to be very close even though there is a risk that the next flash may be at the observer's location. In addition, the lower the storm's flash rate, the farther apart successive flashes tend to be. These results make it difficult to formulate a practical recommendation on the safe distance for every flash.

Some topics were not fully resolved by the attendees. For example, it often is not easy to identify a safe location. Shelters from rain, sun, and wind at golf courses, parks, forests, campgrounds, lakes, rivers, ocean shores, and similar locations are often not safe from lightning and should be identified as such with signs. Another uncertainty is how lightning currents propagate through water and over the ground. Further advances in both basic and applied science are needed to address these questions.

Multidisciplinary efforts are needed in order to understand how to avoid the lightning hazard better and how to treat lightning victims. We hope that the above discussions will eventually lead to a reduction in the number of people who are lightning victims each year.

Acknowledgments. We appreciate the very constructive participation of the individuals involved in the LSG meeting, those with whom we collaborate frequently, and others who are interested in the problem. It has been difficult to separate the categories of participants and collaborators, but the responsibility for unintentional oversights or omissions is entirely ours. We thank Mr. Lee Lawry of Global Atmospherics, Inc., for reviewing the manuscript prior to submission, as well as Dr. E. Philip Krider of The University of Arizona and two anonymous reviewers of the manuscript for their comments.

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