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UPDATED RECOMMENDATIONS FOR LIGHTNING SAFETY-1998

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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 (Figure 1). However, no warnings or forecasts are typically issued for lightning, which is reported by the 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 U.S. After taking into account the underreporting of lightning deaths and injuries (L et al. 1993), about 100 people are estimated to be killed and more than 500 injured by lightning in the U.S. each year. 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 L (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 U.S. every day in summer, and nearly every day during the rest of the year. Since lightning strikes the ground in such large numbers 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 (1992) 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 (1992) 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 Annual Meeting in Phoenix in January 1998. The LSG was comprised of people who were known to be active in lightning safety and education issues, but by no means was 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 the meeting are listed in Table 1. Also included are people who are active in these lightning safety and education issues, but 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 AMS Bulletin.

2. The recommendations

a. Abstract

On average, lightning causes more casualties annually in the US than any other storm related phenomena, except floods. Many people incur injuries or are killed due to misinformation and inappropriate behavior during thunderstorms. A few simple precautions can reduce many of the dangers posed by lightning. 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" (LSG) first convened during the 1998 American Meteorological Society Conference in Phoenix, Arizona to outline appropriate actions under various circumstances when lightning threatens.

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.

The individual is ultimately responsible for his/her personal safety and has the right to take appropriate action when threatened by lightning. 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.

*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 (see NFPA 780, Appendix E & H).

*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, 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 an individual can see lightning and/or hear thunder he/she is 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 should be in, or seek a safer location (see Safer Locations during Thunderstorms and Locations to Avoid). 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 notifying individuals to take action. Many lightning casualties occur in the beginning, as the storm approaches, because people ignore these precursors. Also, many lightning casualties occur after the perceived threat has passed. 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.

*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 ten minutes

*An action plan must be known in advance by all persons involved (see Important Components to an Action Plan, P.5). School teachers, camp counselors, lifeguards, and other 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. 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. Considerations for large groups and/or when the evacuation time is more than ten minutes

*An action plan must be known in advance by all persons involved (see Important Components to an Action Plan). 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.

*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.

*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 days and even hours ahead of an event.

*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.

*The "All Clear" signal must be identified and should be considerably different than 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.

h. First aid recommendations for lightning victims

Most lightning victims can actually survive their encounter with lightning, especially with timely medical treatment. 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 moving them. 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 twenty to thirty 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 et al. 1988) was used in prior safety recommendations (Vavrek et al. 1993; Holle et al. 1995). But L 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 kilometers 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 Atmospheric, 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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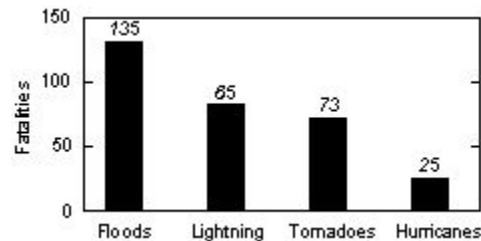


FIGURE 1. Annual number of storm-related deaths in the U.S. from 1966-1995 (from Storm Data, National Climatic Data Center, NOAA, Asheville, N. C.).

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

<i>Affiliation</i>	<i>Location</i>	<i>Discipline</i>	<i>Participant</i>
The College of William & Mary	Williamsburg, Va.	Athletic trainer	B. Bennett
Lightning Protection Technology	Tucson, Ariz.	Engineer	L. Byerley
University of Illinois at Chicago	Chicago, Ill.	Emergency physician	M. A. Cooper
Global Atmospheric, Inc.	Tucson, Ariz.	Engineer	K. L. Cummins
National Severe Storms Laboratory	Norman, Okla.	Research meteorologist	R. L. Holle
National Severe Storms Laboratory	Norman, Okla.	Research meteorologist	W. Howard
National Lightning Safety Institute	Louisville, Colo.	Engineer, president	R. Kithil
University of Arizona	Tucson, Ariz.	Professor	E.P. Krider
Global Atmospheric, Inc.	Tucson, Ariz.	Product manager	L. C. Lawry
National Severe Storms Laboratory	Norman, Okla.	Research meteorologist	R. E. L
St. Paul Fire and Marine Insurance Co.	St. Paul, Minn.	Loss control specialist	B. Lunning
NASA, J.F. Kennedy Space Center	Florida	Manager	J. T. Madura
Quality Protection Systems, Inc.,	Rochester, N. Y.	Engineer, president	M. McGee
U. S. Air Force	Patrick AFB, Fla.	Meteorologist	W. P. Roeder
Eggers Middle School	Hammond, Ind.	Science teacher	J. Vavrek

Global Atmospheric, Inc.	Tucson, Ariz.	Safety management	C. Zimmermann
	<i>Collaborators not at meeting</i>		
Indooroopilly Medical Centre	Chapel Hill, Australia	Medical doctor, engineer	C. Andrews
Colorado Lightning Data Center	Denver, Colo.	Physician	M. Cherington
Anubis & Bastet Productions	Tucson, Ariz.	Writer	G. Harwood
Electricit�e France	Paris, France	Physician	Gourbi航
Eastern Michigan University	Ypsilanti, Mich.	Geography professor	C. Ojala
The Chicago Medical School	North Chicago, Ill.	Psychology professor	M. Primeau
East Carolina Univ.	Greenville, N. C.	Sports medicine physician	K. M. Walsh

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