Updated Recommendations for Lightning Safety – 2002

INTRODUCTION. Lightning has been the second greatest cause of storm-related deaths (after floods) in the United States during the past 40 years. Fortunately, however, through public awareness and the applications of safety guidelines, the vast majority of lightning casualties (deaths and injuries) can be easily avoided. The American Meteorological Society has recently approved a Statement on Lightning Safety Awareness (www.ametsoc.org/AMS) which exhorts all citizens, but especially those responsible for the safety of groups engaging in outdoor activities, to further their awareness of lightnings safety issues. The National Weather Service, in conjunction with cooperating organizations including the Red Cross, has initiated a Lightning Safety Awareness Week (www.lightningsafety.noaa.gov). This paper provides supplemental information to the AMS Statement as well as assembles background materials benefiting all involved in lightning safety awareness activities. It also serves as an update to a review of the topic published in the Bulletin in 1999 (Holle et al., 1999).

Lightning kills more people each year on average than hurricanes and tornadoes combined. When corrected for underreporting, there are about 100 lightning fatalities annually in the United States (Cherington et al., 1999). Beyond the tragic loss of life, however, are the many injuries. Only about 10% of lightning strike victims are killed; 90% survive. But many of the estimated 1000 survivors suffer severe, life-long injury and disability.

It is common for people to refer to the chance of being struck by lightning as an improbable or unlikely event. Yet actual statistics say otherwise. Lightning strikes the ground approximately 25 million times each year in the United States (Orville and Huffines, 2001). Most people greatly underestimate the probability of being involved in a lightning strike. According to the National Weather Service, the chance of an individual in the United States being killed or inured during a given year is one in 240,000. Assuming an average life span of 80 years, a person's odds over their lifetime becomes one in 3000. Assuming the average person has ten family members and others with whom they are close, then the chances are one in 300 that a lightning strike will closely affect a person during their lifetime.

Although absolute personal protection from lightning cannot reasonably be achieved, following a set of simple guidelines can substantially reduce lightning casualties. The vast majority of lightning casualties can be avoided through improved public education. The public needs to be made aware of the magnitude of the lightning hazard and motivated to practice lightning safety. The following background information will provide some insights into issues related to lightning safety, including the physics of lightning, lightning climatology, lightning casualty demographics, and the medical aspects of lightning strikes.

LIGHTNING PHYSICS. Lightning can strike many kilometers from the parent thunderstorm, well outside the rain area and even beyond the visible thundercloud (Lopez and Holle, 1999). Lightning can also strike from debris clouds several tens of minutes after the parent thunderstorm has decayed. Thus lightning safety requires a large standoff distance from thunderstorms and a long standoff time after apparent thunderstorm decay.

Lightning does not "decide" where it will strike until the stepped leader descending from the cloud is about 30 m from the ground or object that is struck. Thus, short objects in an open area can be struck by lightning even if a tall object is nearby. If lightning strikes a nearby object, shock can result either by direct contact or a side flash. If lightning strikes the ground, the high voltage gradients cause currents to flow in concentrated channels on the surface or within the soil, and can injure people nearby. The associated step voltages and surface arcs, respectively, can be deadly more than 40 m from the lightning strike point. In addition, there can be upward discharges tens of meters in length from tall objects (including people) that are located within tens of meters from the strike point.

Thunder produced by a lightning strike travels one mile (1.6 km) every five seconds. Thus, counting the number of seconds between the visible "flash" and the audible "bang" and dividing by 5, provides the distance in miles. In noisy urban areas, thunder may not be audible more than a few miles from the flash, and is rarely heard for distances of more than 10 miles (16 km) even in the most quiet environments. The distance between successive lightning strikes in some thunderstorms can be as large as 5 miles (8 km) — at times even more.

LIGHTNING CLIMATOLOGY. The average areal density of cloud-to-ground lightning flashes in the contiguous United States has been objectively measured by the National Lightning Detection Network (NLDN). The greatest flash density is found in central Florida, where each square kilometer is struck more than ten times each year. High flash densities are also

found throughout the Southeast and Midwest. Almost half the nation has a flash density greater than 4 flashes per square kilometer per year. No place in the United States is totally free of a lightning threat. Also, the annual average flash density can be misleading. Some places may have a low flash density over 12 months, but a high peak seasonal value. For example, for a few weeks in summer, the Front Range of the Rocky Mountains in Colorado approaches the flash density of Florida. Also, some intense mesoscale convective systems can unleash more than 100,000 flashes during their life span while traversing several states.

While lightning can occur anywhere and anytime during the year, lightning activity has a strong annual cycle in the United States. The lightning rate shows a broad peak in summer centered on July, with a rapid increase during May and a rapid decrease in September. The lightning flash rate continues to decrease through winter, with a minimum occurring during January. Most lightning occurs during the afternoon or early evening, between 1200 and 2000 LST, peaking at about 1600 LST. Portions of the upper Midwest have a evening or nocturnal peak between 2000 and 0400 LST (Orville and Huffines, 2001).

LIGHTNING CASUALTY DEMOGRAPHICS. Lightning casualty statistics reflect geographical differences in lightning strike density, population density, outdoor activity levels and public lightning threat awareness. Casualties occur most often during July, and between 1200 and 1800 LST, with the peak around 1600 LST. Sunday has the most casualties, followed closely by Saturday. Late afternoon is the deadliest period. Males are struck by lightning in significantly greater numbers than females. These factors presumably reflect higher rates of outdoor exposure.

The relative frequency of lightning casualties in the United States by location or activity is listed in Table1. When lightning is imminent or occurring, avoid these activities like your life depends on it — it does. The studies from which these results are taken did not include higher elevation as a factor. Though not listed here, higher elevation produces an enhanced risk when thunderstorms threaten.

Many lightning casualties occur before the thunderstorm rains have moved into the area. The casualty rate actually decreases while the rainstorm is in progress and people seek inside shelter — from the rain. Even larger numbers of casualties occur after the rain dissipates. People, in too much of a hurry to go back outside, ignore the fact that lightning continues to be a threat outside the precipitation areas.

In terms of absolute numbers of lightning casualties, the top five states are, in order: Florida, Michigan, Pennsylvania, North Carolina, and New York. But a more meaningful measure is the number of lightning casualties per capita; the top five states become, in rank order: Wyoming, New Mexico, Florida, Arkansas, and Colorado. The Rocky Mountains states have both relatively low annual lightning flash and population densities, yet many people tend to be outside precisely when the lightning hazard is at its greatest. The degree of outdoor at-risk behavior in occupation and recreation, combined with poor public awareness can lead to distressingly high casualty rates. All states have some degree of lightning threat and all persons should be aware of the need for and practice lightning safety.

MEDICAL ASPECTS OF LIGHTNING. Medical authorities have recently been learning more about the range of impacts of lightning on its victims (Cooper, 1995). The medical aspects of lightning are detailed on several of the websites listed in Table 1, and a few key highlights are presented here. If there are lightning casualties, immediately calling “9-1-1” for assistance is paramount. Death results from cardiac arrest and/or stopped breathing at the time of the strike. First aid for lightning strike victims is CPR or mouth-to-mouth resuscitation, respectively. Medical authorities recommend that if numerous persons are involved in a lightning incident, treat the apparently dead first — as many can be revived. While only about one in ten of those struck by lightning now die, lightning victims often suffer severe, life-long debilitation. These injuries are primarily neurological, with a wide range of symptoms, and are sometimes difficult to diagnose. The most frequent symptoms are memory deficit, sleep disturbance, chronic pain, dizziness, and chronic fatigue. These symptoms may not appear or be recognized until some time after the lightning injury, sometimes months after the initial injury. Lightning survivors sometimes have trouble processing information, are easily distracted, and have personality changes. These impair their ability to earn a living and maintain relationships, which exacerbates the psychological problems lightning survivors often have in dealing with their injuries. Family, friends, and colleagues need to continue providing emotional support and not abandon or isolate them. “Lightning Strike Electric and Shock Survivors International” is the main support group for lightning survivors and provides an invaluable service.

BASIC LIGHTNING SAFETY GUIDANCE. The following guidelines have been compiled by lightning safety experts and reflect the current thinking on this topic. Please note the knowledge base on lightning is continuously expanding so readers are advised to keep abreast of new developments as they occur.

The National Weather Service routinely issues watches and warnings for thunderstorms that can produce tornadoes and other severe weather (high winds and large hail). It does not, however, issue warnings based solely upon lightning. Moreover, a storm need be neither tornadic nor severe in order to produce copious numbers of lightning strikes. When considering lightning any thunderstorm, by definition, has the potential to produce a "severe" lightning strike. While adhering to lightning safety rules can at times be inconvenient, one must consider the alternative of not following these simple measures. Adults are responsible for the safety of children under their care; this includes matters of lightning safety. In this spirit, the National Collegiate Athletic Association (NCAA) has issued guidelines for lightning safety for those in charge of team sports. K–12 educators have become active in promoting lightning safety on schools (Roeder et al., 2001). Ultimately each of us is responsible for our own safety during lightning storms. The most important fact is to realize that no place outdoors is safe when thunderstorms are nearby. Implementing a lightning safety and awareness plan is a multi-level process:

Level-1: If you are planning outdoors activities, obtain the weather forecast beforehand. Schedule outdoor activities around the weather to avoid exposure to the lightning hazard. Know your local weather patterns.

Level-2: If you are planning to be outdoors, identify and stay within travelling range of a proper shelter. Employ the "30–30 Rule" to know when to seek a safer location. The "30–30 Rule" states that when you see lightning, count the time until you hear thunder. If this time is 30 seconds or less, go immediately to a safer place. If you can't see the lightning, just hearing the thunder means lightning is likely within striking range. After the storm has apparently dissipated or moved on, wait 30 minutes or more after hearing the last thunder before leaving the safer location.

The "30–30 Rule" is best suited for existing thunderstorms moving into the area. However, it cannot protect against the first lightning strike. Be alert to changes in sky conditions portending thunderstorm development directly overhead. Larger outdoor activities, with longer evacuation times, may require a longer lead-time than implied by the "30–30 Rule."

Level-3: When lightning threatens, go to a safer location. Do not hesitate. The lightning casualty lore is replete with tales of persons just about to make it to safety when they were struck. Even a few extra minutes lead time can be life saving.

What is a safer location? The safest place commonly available during a lightning storm is a large, fully enclosed, substantially constructed building, e.g. your typical house, school, library, or other public building. Substantial construction also implies the building has wiring and plumbing, which can conduct lightning current safely to ground. However, any metal conductor exposed to the outside must not be touched precisely because it could become a lightning conduit. Once inside, stay away from corded telephones, electrical appliances, lighting fixtures, ham radio microphones, electric sockets and plumbing. Don't watch lightning from open windows or doorways. Inner rooms are generally preferable from a safety viewpoint.

If you can't reach a substantial building, an enclosed vehicle with a solid metal roof and metal sides is a reasonable second choice. As with a building, avoid contact with conducting paths going outside. Close the windows, lean away from the door, put your hands in your lap and don't touch the steering wheel, ignition, gear shifter or radio. Convertibles, cars with fiberglass or plastic shells, and open-framed vehicles are not suitable lightning shelters.

Level-4: If you cannot flee to a safer location, take action to minimize the threat of being struck. Proceed from higher to lower elevations. Avoid wide-open areas, including sports fields, beaches and golf courses. Avoid tall, isolated objects like trees, poles, and light posts. Avoid water-related activities such as swimming (including indoor pools), boating and fishing. Do not remain in open vehicles like farm tractors, cabless construction machinery, riding lawnmowers and golf carts (sun roofs offer no protection). Do not consider unprotected open structures such as picnic pavilions, rain shelters and bus stops. Avoid contact with metal fences, metal bleachers, or other long metal structures. And the cardinal rule remains**:** Do not take shelter under trees to keep dry during thunderstorms.

Level-5: If circumstances or a series of bad decisions have found you outside of a shelter, far removed from a safer place when lightning is occurring, there are still measures to be taken. If lightning is about to strike, it will sometimes provide a very few seconds of warning. Sometimes your hair may stand on end, your skin will tingle, light metal objects will vibrate or you will hear a crackling or "kee-kee" sound. If this happens and you're in a group, spread out so there are several body lengths

between each person. Once you've spread out, use the lightning crouch. Put your feet together, squat down, tuck your head, and cover your ears. When the immediate threat of lightning has passed, continue heading to the safest place possible.

Level-6: If the worst happens, there are key Lightning First Aid guidelines. First, if at all possible, call "9-1-1" immediately. Since all deaths from lightning strikes result from cardiac arrest and/or stopped breathing, begin treatment as soon as possible. CPR or mouth-to-mouth-resuscitation is the recommended first aid, respectively. It is an enduring myth that strike victims retain electrical charge. They do not. There is no hazard posed to a care giver. If the storm's lightning is ongoing and represents a continuing risk to responders, consider moving the victim to a safer location

No lightning safety guidelines will provide 100% guaranteed total safety, but the preceding guidelines will greatly minimize the lightning hazard to humans.

LIGHTNING DETECTION TECHNOLOGY. Hand-held lightning detectors have become more affordable and more popular in recent years. While potentially helpful it should be noted their performances may not been have been independently, rigorously and objectively verified. There is anecdotal evidence that some can fail to detect weak and/or intermittent, but still deadly, lightning. There are also many examples of people installing and using the detectors incorrectly. Moreover, these devices should be used only as a back-up to the "30–30 Rule." There are commercial services available which will provide automatic notifications when lightning has been detected by the National Lightning Detection Network (NLDN) within user-specified distances to an activity/site. The alert can be sent via pager, fax, e-mail or cell-phone. These services are reasonably priced and can be a useful component of a lightning safety plan for organized outdoor activities. Alternately, private forecasting firms can provide tailored lightning alerts along with additional weather related services. The best detection technology, however, cannot provide long lead times from a thunderstorm forming rapidly overhead. Thus, in the end, those responsible must still watch the sky for developing thunderstorms and be ready to proceed to a safer location hopefully before the first lightning is produced.

SUMMARY. Lightning is *the* underrated storm-related weather hazard. Until recently, relatively little attention has been paid to lightning safety, as compared to tornado, hurricane and flood safety. Perhaps because its victims often fall one at a time, without graphic property destruction, it garners less media attention. Fortunately, the vast majority of lightning's casualties can be easily, efficiently and inexpensively avoided. Public education is the key. The public, especially those charged with managing outdoor activities, must become more aware of the magnitude of the hazard and become educated about lightning safety procedures.

The meteorological community can play a key role in improving this aspect of weather safety in the United States and around the world. We call on professional meteorologists, especially broadcasters and those in a position to affect the required changes, to proactively engage the public in lightning safety education. Lightning Safety Awareness Week, organized by the National Weather Service in conjunction with partnering organizations, is an excellent example of an effective public awareness activity. Table 2 is a compilation of Internet resources that can provide additional information and support.

REFERENCES

Cherington, M., J. Walker,. M. Boyson, R. Glancy, H. Hedegaard and S. Clark, 1999: Closing the gap on the actual numbers of lightning casualties and deaths. Preprints, *11th Conf. on Applied Climatology*, Dallas, TX, Amer. Meteor. Soc., 379-380.

Cooper, M.A., 1995: Emergent care of lightning and electrical injuries. *Sem. Neurol*., **15**, 268-278.

Cummins, K.L., M.J. Murphy, E.A. Bardo, W.L. Hiscox, R.B. Pyle and A.E. Pifer, 1998: A combined TOA/MDF technology upgrade of the U.S. National Lightning Detection Network. *J. Geophys. Res.,* **103** (D8), 9035-9044.

Holle, R.L., R.E. Lopez and C. Zimmermann, 1999: Updated recommendations for lightning safety – 1998. *Bull. Amer. Meteor. Soc.,* **80**, 2035 – 2041.

Lopez, R. E., and R.L. Holle, 1999: The distance between successive lightning flashes. NOAA Tech. Memo. ERL NSSL-1XX, National Severe Storms Laboratory, Norman, OK, 28 pp. [Available from NSSL, 1313 Halley Circle, Norman, OK 73069.]

Orville, R.E. and G.R. Huffines, 2001: Cloud-to-ground lightning in the United States: NLDN results in the first decade, 1989-1998. *Mon. Wea. Rev.,* **129**, 1179-1193.

Roeder, W.P., R. J. Vavreck, F.C. Brody, J.T. Madura and D. E. Harms, 2001: Lightning safety for schools. Preprints, *10th Symposium on Education*, Albuquerque, NM, Amer. Meteor. Soc., 89-91

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TABLE-1: Lightning Casualties In The U.S. By Location Or Activity

RANK	LOCATION / ACTIVITY	RELATIVE FREQUENCY
1	Open Areas (including sports fields)	45%
2	Going Under Trees To Keep Dry	23%
3	Water Related Activities (swimming, boating, and fishing)	14%
4	Golfing (while in the open)	6%
5	Farm And Construction Vehicles (with open exposed cockpits)	5%
6	Corded Telephone (#1 indoor source of lightning casualties)	4%
7	Golfing (while mistakenly seeking "shelter" under trees)	2%
8	Using Radios And Radio Equipment	1%

TABLE-2: Lightning Safety Education Resources (as of 20 February 2002)

ORGANIZATION	WEBSITE
National Weather Service	www.LightningSafety.noaa.gov
45th Weather Squadron, US Air Force	https://www.patrick.af.mil/45ws/45og/LightningSafety/index.html
National Severe Storms Laboratory	www.nssl.noaa.gov/researchitems/lightning.html
National Lightning Safety Institute	www.LightningSafety.com/index.html
'USA Today' Newspaper	www.usatoday.com/weather/thunder/wlightning.htm
American Red Cross–Masters of Disaster (Children's Curriculum)	www.redcross.org/disaster/masters/
Kids' Lightning Safety (aka Sabrina's Website)	www.azstarnet.com/anubis/zaphome.htm
National Collegiate Athletic Association	http://www.ncaa.org/sports_sciences/sports_med_handbook/1d.pdf
National Athletic Trainers' Association	www.nata.org/publications/otherpub/lightning.pdf
National Outdoor Leadership School—Backcountry Guidelines	research.nols.edu/wild_instructor_pdfs/lightningsafetyguideline.pdf
University Of Florida (Boating–Lightning Safety)	www.thomson.ece.ufl.edu/lightning
National Agricultural Safety Database (Boating–Lightning Protection)	www.cdc.gov/niosh/nasd/docs/as04800.html
Lightning Injury Research (University of Illinois at Chicago)	www.uic.edu/labs/LightningInjury
Lightning Strike and Electric Shock Survivors, Intl.	www.Lightning-Strike.org
Global Atmospherics, Inc. (National Lightning Detection Network)	www.LightningStorm.com