2010 21st International Lightning Detection Conference
19 – 20 April • Orlando, Florida, USA
3rd International Lightning Meteorology Conference
21 – 22 April • Orlando, Florida, USA

Lightning Safety Procedures For The Public

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1. Introduction

Lightning is the second leading cause of storm related deaths in the United States (U.S.), only floods kill more (NOAA, 2009). Lightning kills more than tornadoes or hurricanes (Figure-1). Lightning also inflicts life-long debilitating injury on many more than it kills (Cooper, 1995). Lightning is also a significant weather hazard outside of the U.S. (Holle and Lopez, 2003). Fortunately, most lightning casualties in the U.S. can be easily, quickly, and cheaply prevented. Public education is the key.

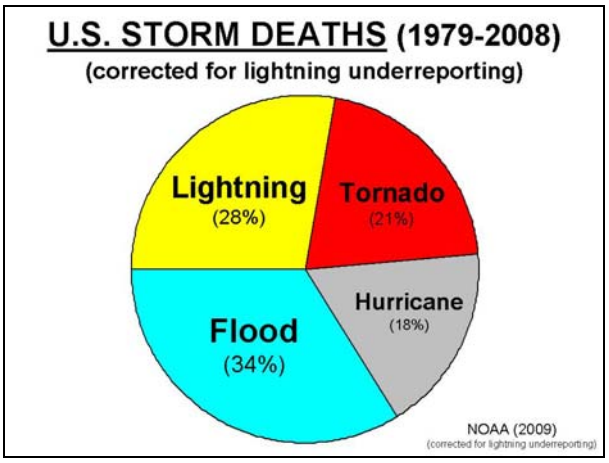

Figure 1. Weather causes of U.S. storm deaths (1979-2008) taken from NOAA Storm Reports (NOAA, 2009), corrected for lightning under reporting (Lopez et al., 1993). The uncorrected storm death rate from lightning is 22.7%. The percentage of hurricane storm deaths is higher than many previous reports because of the 2004-2005 hurricane seasons with numerous U.S. landfalls, especially the disastrous Hurricane Katrina.

The percentage of storm deaths from lightning in the U.S. has been steadily declining (Figure-2). The latest 10-year average (1999-2008), rather than the standard 30-year average in Figure-1, shows lightning has dropped to the third leading source of storm deaths after tornadoes, contributing 20% and 23%, respectively, even when lightning is corrected for underreporting. Indeed, 2008 set a new record low number of lightning deaths in the U.S. and 2009 also had a very low number. However, a 10-year average is not recommended since it can be skewed by a single large event such as Hurricane Katrina in 2005 or the record low lightning deaths in 2008. While U.S. lightning deaths have been generally declining, it remains a significant hazard, especially considering the frequent life-long debilitating injuries. Therefore, lightning safety public education is still required. Indeed, the declining rate suggests that the public education has been effective and that further improvements are still possible.

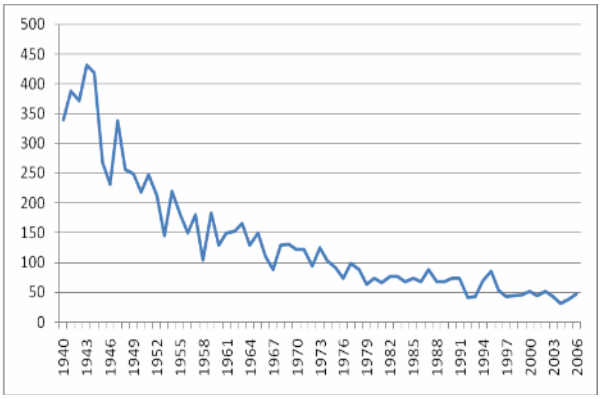

Figure 2. Lightning fatalities for the United States from 1940 through 2006 (NOAA 2007).

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Meteorologists can play a profound role in the battle against lightning casualties by increasing public awareness of the lightning threat and of the lightning safety guidelines. The author encourages the professional meteorological community to join this vital public service to save lives and prevent debilitating injuries, especially broadcast meteorologists with their ready access to large audiences. A recommended 5-level approach is provided below. The National Weather Service has sponsored an annual lightning safety awareness week since 2001 (Jensenius et al., 2008). This event is the last full week of June and provides useful resources on teaching lightning safety at their website (www.lightningsafety.noaa.gov). Interested parties may also contact the author for assistance.

2. The 5-Levels Of Lightning Safety

Lightning safety education requires that consistent information be presented to the public. Fortunately, there is strong consensus on what constitutes good lightning safety. A 5-level method for teaching lightning safety is presented that is consistent with that consensus and that has proven useful in public education (Roeder, 2007a; Lushine et al., 2005). These 5-levels are briefly summarized in Table-1. The fundamental principle of lightning safety is:

- **No** Place Outside Is Safe,
  When Thunderstorms Are In the Area!

Useful slogans for teaching lightning safety are in Table-2. Several refinements to lightning safety have occurred in recent years and are briefly summarized in Table-3. The 5-levels of lightning safety presented here include these recent refinements.

2.1 Level-1: Schedule Outdoor Activities

In any safety procedure, avoiding the risk is best. Schedule your outdoor activities to avoid the lightning threat. Plan ahead; watch the weather forecast and know your local weather patterns. Within the U.S., forecasts are available from local National Weather Service offices, available by entering the desired zip code, city and state, or by clicking on the desired office on the U.S. map at the National Weather Service website (www.weather.gov). Since the National Weather Service does not issue weather warnings just for lightning, look for the words 'thunderstorm', 'lightning-storm', and 'lightning' in the forecast.

2.2 Level-2: Know When And Where To Go For Lightning Safety

Knowing when and where to go for lightning safety is a key component for protecting yourself from lightning.

2.2.1 When To Go For Safety

Watch the skies for approaching or locally developing threatening clouds and listen for thunder. When you hear thunder, quickly go to a place that is safe from lightning. Stay there for 30 minutes or more after hearing the last thunder. The amount of time indoors may feel inconvenient, but must be followed diligently. The 30 minute part is especially important since half or more of lightning casualties occur after the storm has moved away or dissipated (Holle et al., 1993). This guidance is consistent with the lightning warning process used by America's space program in FL (Weems et al., 2001) and the distribution of lightning strike distances and timing (Holle et al., 2003) (McNamara, 2002) (Nelson, 2002). This guidance is summarized by the following two easy-to-remember slogans:

- When Thunder Roars, Go Indoors!
- Half An Hour Since Thunder Roars,
  Now It's Safe To Go Outdoors!

These slogans replace the '30-30 Rule'. The '30-30 Rule' said to be in a safe place when there is 30 seconds or less between lightning and its thunder, and to wait 30 minutes or more after hearing the last thunder before leaving the safe place. Unfortunately, many people misunderstood the '30-30 Rule' to be go to a safe place at the 30 second threshold, rather than already be there by that time. Despite strong attempts by the lightning

TABLE 1.
Quick Reference For The Five Levels Of Lightning Safety

LEVEL (best to worst)	**BRIEF DESCRIPTION**
Fundamental Principle: **No** place outside is safe, when thunderstorms are in the area.	
1	Schedule outdoor activities to avoid lightning.
2	Know when and where to be in a safe place. • When thunder roars, go indoors! • Half an hour since thunder roars, now it's safe to go outdoors! Safe places are a large fully enclosed building with wiring and plumbing, e.g. house, school, store, etc., or a vehicle with a solid metal top and solid metal, e.g. most cars, trucks, or buses.
3	Avoid dangerous locations/activities (elevated places, open areas, tall isolated objects, and water related activities (swimming, boating, near edge of bodies of water)). Do **NOT** go under trees to keep dry in thunderstorms!
4	No-notice personal outdoor lightning risk reduction, including the 'lightning crouch' is no longer advocated for general audiences (Roeder, 2008a), but it may be appropriate for groups that spend a lot of time outdoors away from safe places from lightning.
5	First Aid: Immediately start CPR or rescue breathing, as needed. Have someone call 9-1-1. Use an AED (do not delay CPR). Continue CPR/rescue breathing if AED won't activate.

TABLE 2.
Lightning Safety Training Slogans

SLOGAN	**SOURCE**
NO Place Is Safe, When Thunderstorms Are In The Area!	Author
When Thunder Roars, Go Indoors!	Author
Half An Hour Since Thunder Roars, Now It's Safe To Go Outdoors!	Author
Lightning Kills--Play It Safe!	National Weather Service
Lightning Ignored, Darwin Award!	McAleenan (2004)
Don't Get Fried, Go Inside!	Author
Don't Be A Fool, Get Out Of The Pool!	Author
Don't Be Lame, End The Game!	Author
Use Your Brain, Don't Wait For Rain!	Lightning Protection Institute
If You Can See It, Flee It!	National Lightning Safety Institute
If You Hear It, Clear It!	National Lightning Safety Institute

TABLE 3.
Recent Updates In Lightning Safety

NO.	**UPDATE**
1	Upgraded the safety provided by vehicles with solid metal tops and solid metal sides
2	Using hearing thunder as cue to seek a safe place (replaces waiting for 30 seconds between lightning and its thunder as in now superseded '30-30 Rule')
3	Distribution of lightning fatalities by age (reinforces previous thinking to target children for lightning safety education)
4	No longer teach no-notice outdoor lightning risk reduction to the general public (though it may be appropriate for limited special groups)
5	Added Automatic External Defibrillator (AED) to lightning first aid
6	Summarized common myths that continue to detract from lightning safety

safety community, and the illogical implication that all situations have the same lead-time to get to safety, this misunderstanding proved difficult to correct. In addition, for fast moving thunderstorms, there is often barely enough time after hearing the first thunder to get to safety. Even in summer, fast moving and frontally driven thunderstorms, especially at higher latitudes. As a result, the lightning safety community revised the first part of the '30-30 Rule' to seek safety when hearing thunder rather than 30 seconds between lightning and its thunder.

Recent research suggests lightning occurs at a distance such that thunder provides sufficient warning in only about half the events (Lengyel et al., 2005). However, that study was based on data from the National Lightning Detection Network that only detects cloud-to-ground lightning, which is only about 30% of lightning. Since most lightning is lightning aloft, it will often provide additional lead-time to hear thunder and recognize the threat, especially since lightning aloft precedes the first cloud-to-ground flashes in about 75% of the events. Thus, the percent of time when thunder provides sufficient safety warning is likely higher than that cited in this research.

One key weakness of listening for thunder is that it may not be audible in noisy environments or in mountainous locations with intervening terrain.

Anther way to keep informed about the local weather is NOAA 'All Hazards' Radio, formerly NOAA Weather Radio, is a useful source of updated weather information. Portable versions can be used in the field. While NWS doesn't issue warnings just for lightning, i.e. the alarm won't be activated, but the repeated weather description and forecast can be used. The word 'lightning' may not be used every time, but if thunderstorms are mentioned, remember that all thunderstorms have lightning. NOAA 'All Hazards' radio is also an excellent way to be alerted to other weather and non-weather hazards. More information on NOAA 'All Hazards' radio is at www.nws.noaa.gov/nwr.

Finally, portable TV and radio can also be used to keep updated on the changing local weather. However, there is no substitute for watching the skies for threatening clouds and listening for thunderstorms.

2.2.2 Where To Go For Safety

One of the best shelters commonly available for lightning is a large fully enclosed building with wiring and plumbing, e.g. a typical house, school, store, or office building, etc. Once inside, stay away from any conducting path to the outside. Stay off corded telephones, except to call emergency services. Stay away from electrical appliances, lightning, and electric sockets. Stay away from plumbing. Don't watch lightning from windows or doorways. In large buildings, inner rooms are generally better.

If you can't get to a proper building, a vehicle with a solid metal roof and metal sides also offers good protection; e.g. a typical car, truck, or school bus. Avoid contact with conducting paths to the outside. If parked, close the windows, lean away from the sides, put your hands in your lap, and don't touch the steering wheel, ignition, gear shifter, or radio. In large vehicles, like school buses, moving to the center is better. If driving, it is generally safer not to park on the side of the road since that increases the chances of collision with other cars. Vehicles that offer no protection from lightning include motorcycles (Cooper and Holle, 2007), convertibles, bicycles, open framed vehicles, and vehicles with fiberglass or plastic shells or fabric tops, etc.

2.2.3 Lightning Detectors

In recent years, inexpensive hand-held lightning detectors have become widely available. Many people are tempted to use these detectors as an objective tool in lightning safety. However, the performance of these commercial products has usually not been independently and objectively verified. In addition to the unknown performance, there is much anecdotal evidence of the devices not locating lightning accurately, or not detecting weak and/or infrequent, but still potentially deadly lightning at all. There is also much anecdotal evidence of the devices being used improperly. Therefore, the

Lightning Safety Group recommended these hand-held detectors not be used, or at most be used as a supplement to the other procedures (Holle et al., 1999).

Professional grade lightning detectors are available commercially. These devices perform well, but are too expensive for most organizations.

2.2.4 Lightning Notification Services

Fortunately, automatic lightning notification services are a reasonable solution to the gulf between inexpensive but unproven hand-held lightning detectors and the good performance but prohibitively expensive professional grade detectors. The services use the data from the National Lightning Detection Network (NLDN) (Murphy et al., 2002), or the U.S. Precision Lightning Network, or WeatherBug to automatically notify you when cloud-to-ground lightning is detected within desired distances of your desired location during your desired time. A three-phase approach is best, such as notification when lightning is first detected within 15 miles, as a heads-up that lightning is approaching or developing nearby so you should review plans and prepare for action. The next notification is for lightning within a distance that allows enough evacuation time before the lightning is within 6 miles. The final notification is for lightning within 6 miles and all outdoor personnel should already be evacuated to safe shelter. These services will also notify you when lightning has not been detected within those distances for your desired time span (typically 30 min). This can serve as an 'all clear' and that outdoor activities may resume with reasonable safety. Notification can be to pagers, cell phones, e-mail, faxes, etc. These automatic lightning notification subscription services are useful since they provide objective decision points. However, there is one key weakness. Some of the systems only provide cloud-to-ground lightning, which is only about 30% of all lightning. The rest of the lightning is aloft, either in-cloud, cloud-to-cloud, or cloud-to-air lightning. Even if the lightning has been overhead and not reported by some of these services, the next flash could be a deadly cloud-to-ground lightning–it is too risky to assume the lightning aloft will continue to remain aloft. A notification service can be used to supplement but not replace listening for thunder.

2.3 Level-3: Risk Reduction

If you can't get to a safe place from lightning and must be outside with thunderstorms in the area, at least avoid the locations and activities with the most risk. Note: it is much safer not to be outside under this situation. Remember -- **No** Place Outside Is Safe, When Thunderstorms Are In The Area! Avoid elevated locations, either mountains/hills or elevated places, such as some playground equipment. Avoid open areas, including sports fields, playgrounds, and golf courses. Avoid tall isolated objects like trees, flagpoles, etc. Do not go under trees to keep dry! Avoid water-related activities such as swimming, boating, and fishing. Avoid open vehicles like grounds keeping equipment (riding lawnmowers, tractors, etc.), open construction vehicles, golf carts (even with roofs), etc. Avoid unprotected open buildings like picnic pavilions, rain shelters, and bus stops. Avoid large or long metal structures like fences and bleachers. A commonly believed myth is that metal attracts lightning. However, if lightning strikes a large metal object by happenstance, the hazardous electricity can be conducted a long distance, increasing the chance of it killing or injuring more people.

2.4 Level-4: No-notice Personal Outdoor Lightning Risk Reduction

The lightning safety community no longer recommends teaching no-notice personal outdoor lightning risk reduction to the public. Remember the fundamental principle of lightning safety – **No** Place Outside Is Safe, When Thunderstorms Are In The Area! However, this topic may still be appropriate for groups that spend time far away from safe locations. This is important since lightning casualties due to outdoor recreational activities far from shelter may be increasing (Holle, 2005b).

Use the lightning crouch and the rest of outdoor lightning risk reduction only as a desperate last resort! This is risk reduction, not safety. If you're far away from a safe location and lightning threatens, rush to the safest location available. If you are in a group, spread out so there are several body lengths between each person as you proceed. That way, if one person is struck, the others may not be hit and can give first aid. If lightning is imminent, it will sometimes give a few seconds of warning. Sometimes your hair will stand upright, skin will tingle, light metal objects will vibrate, or you'll hear a crackling static-like sound. If this happens, immediately warn the others and immediately use the lightning crouch; put your feet together, squat down, tuck your head, and cover your ears. After several seconds, slowly stand up looking for the signs that lightning is still imminent. If you detect any of those signs, immediately drop back into the lightning crouch. If you can stand up without detecting any of the lightning signs, continue rushing to the safest spot possible. Once at the safest spot available, the group should remain several body lengths apart, remain alert for the signs of imminent lightning, warn the others in your group and use the lightning crouch as before. You are much safer having followed the previous levels and not been in high-risk situations.

2.5 Level-5: First Aid

All deaths from lightning are from cardiac arrest or stopped breathing from the cardiac arrest. Immediately start CPR or rescue breathing if the person has no pulse or is not breathing, respectively. Next, have someone else call 9-1-1 for professional emergency medical care. Use an Automatic External Defibrillator (AED), if available. Do not delay CPR or rescue breathing to look for an AED. If the cardiac arrest is a ventricular fibrillation, the AED will perform much better than CPR. If the cardiac arrest is not a ventricular fibrillation, the AED won't activate and CPR should be continued until emergency medical technicians arrive and take over the first aid.

3. Lightning Casualty Demographics

The patterns of lightning casualty demographics are extremely useful in targeting and tailoring lightning safety education. The following data indicate that to reduce current lightning casualties, education should emphasize males, and for long-term reduction of lightning casualties, education should focus on children under the age of 10.

The frequency of lightning deaths versus location or activity in the U.S. is in Figure-3 and for youths in Florida is in Figure-4. This distribution for youths should be broadly applicable across the U.S., except the percent from water activities may be smaller.

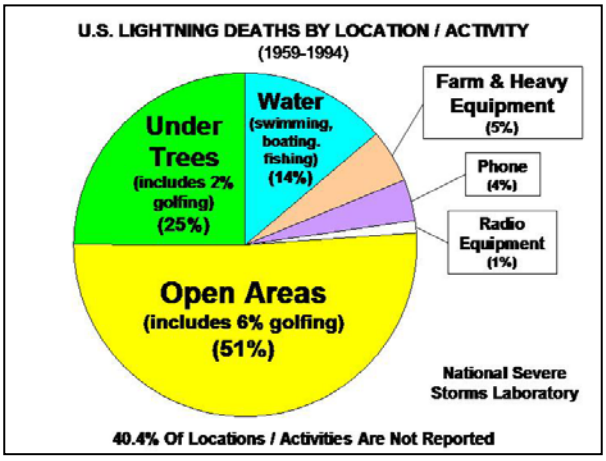

Figure 3. U.S. lightning casualties by location or activity (Curran et al., 2000).

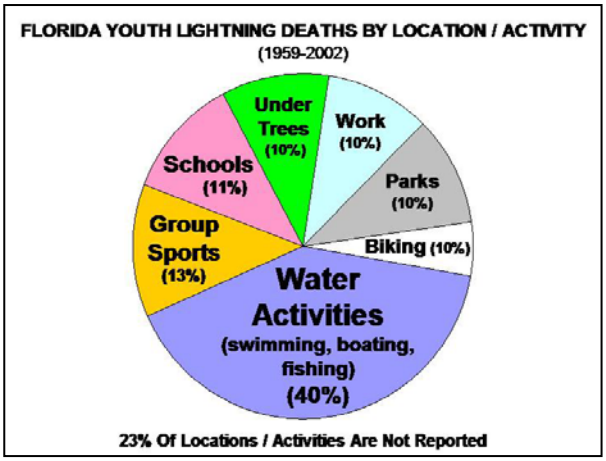

Figure 4. Location/activity of youth lightning fatalities in Florida.

Outdoor sports activities need to be especially sensitive to the need to go inside quickly. Recent studies indicate that far too many sports activities have lightning casualties even during the game (Holle, 2005a). The officials are not seeking shelter quickly enough. While all outdoor school activities are at risk from lightning, activities that are far away from proper shelter are especially risky. Examples include golf teams and cross country teams. Water related activities are also especially risky, e.g. some school sports programs include boating. Indoor pools are also a concern since their plumbing and wiring can conduct the electricity from nearby strikes into the water. A vehicle with a solid metal roof and solid metal sides, e.g. a school bus, can be used to pick-up students in activities far away from proper shelter. Such a vehicle provides good protection against lightning. In addition, lightning casualties during outdoor recreation have been increasing (Holle, 2005b).

The distribution of lightning fatalities by age in the U.S. and normalized by the percent of population are in Figure-5 and Figure-6, respectively. The normalization is done to account the percentage of population for that age group, i.e. a value of one means the lightning fatality rate is as expected for that age group's population.

The distribution of lightning casualties by gender is in Figure-7.

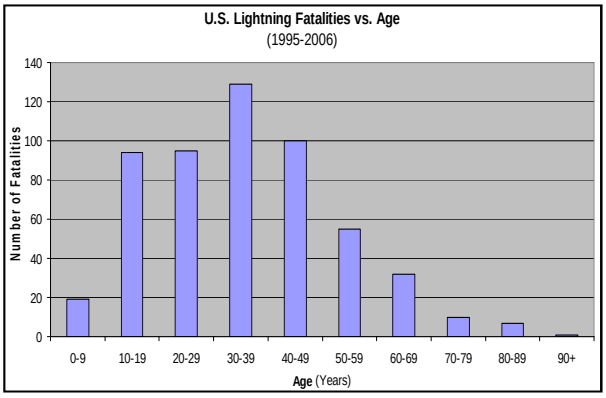

Figure 5. Lightning fatalities in the U.S. by age from NOAA Storm Reports (NOAA, 2007).

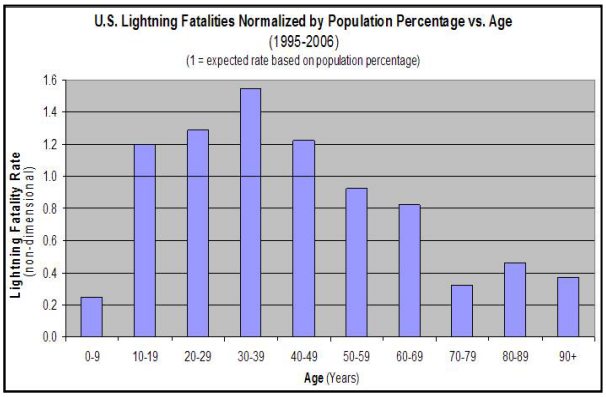

Figure 6. Normalized lightning fatalities in the U.S. by age (NOAA, 2007). Age groups with a normalized lightning fatality rate > 1 are more at risk than expected from the relative size of their population.

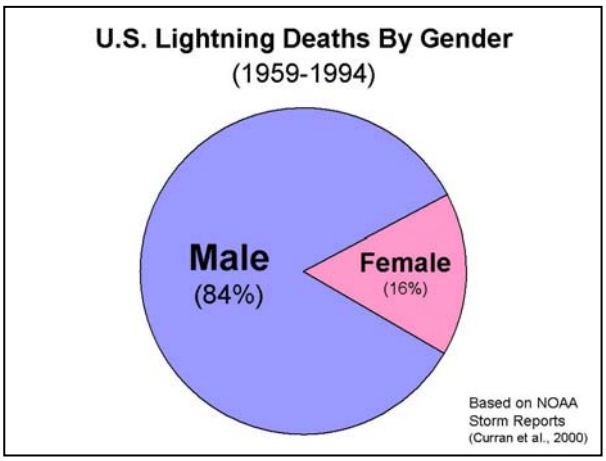

Figure 7. Distribution of lightning fatalities in the U.S. by gender. This approximate ratio has been observed in other studies for the U.S. and Florida. Data from NOAA Storm Reports (Curran et al., 2000)

4. Resources To Teach Lightning Safety

Many resources are available to help teach lightning safety (Roeder, 2007a). The NOAA lightning safety website is especially useful (www.lightningsafety.noaa.gov). Other useful websites are listed in Table-4.

TABLE 4.
Lightning Safety Websites

ORGANIZATION	URL	COMMENTS
GENERAL		
National Weather Service	www.lightningsafety.noaa.gov	Premier overall lightning safety website. Home of Lightning Safety Awareness Week.
National Severe Storms Laboratory	www.nssl.noaa.gov/edu/safety	None
National Lightning Safety Institute	www.lightningsafety.com	None
'USA Today' Newspaper	www.usatoday.com/weather/thunder/wlightning.htm	None
StruckByLightning.Org	www.struckbylightning.org	Non-profit organization for lightning safety education (new video demonstrations on the power of lightning (Mar 2010))
CHILDREN		
Kids' Lightning Safety	www.kidslightning.info	Aka "Sabrina's website"
Kidstorm	www.skydiary.com/kids/lightning.html	None
National Severe Storms Laboratory	www.nssl.noaa.gov/edu/bm	Downloadable coloring books on thunderstorm safety
SPORTS AND OTHER OUTDOOR ACTIVITIES		
American Red Cross--Masters of Disaster	www.redcross.org	Children's curriculum
National Collegiate Athletic Association	http://www.ncaapublications.com/Uploads/PDF/SportsMedHandbook_update_12_212848760d-cbd5-47d7-be71-9e152518e0b9.pdf	None
National Athletic Trainers Assoc.	http://www.nata.org/statements/position/lightning.pdf	None
National Outdoor Leadership School	research.nols.edu/wild_instructor_pdfs/lightningsafetyguideline.pdf	None
Marine Lightning Protection, Inc.	www.marinelightning.com	Boating--lightning safety
National Agricultural Safety Database	http://nasdonline.org/document/209/d000007/boating-lightning-protection.html	Boating--lightning protection
MISCELLANEOUS		
Lightning Injury Research (Univ. Illinois at Chicago)	www.uic.edu/labs/lightninginjury	None
Lightning Strike and Electric Shock Survivors, International	www.lightning-strike.org	Support group
Vaisala, Inc.	http://www.vaisala.com/weather/products/realtimedata.html	National Lightning Detection Network
Time Of Arrival Systems, Inc.	http://www.uspln.com/index2.html	U.S. Precision Lightning Network
WeatherBug	http://weather.weatherbug.com/weatherbug-professional/products/total-lightning-network	Total Lightning Network
National Weather Service Headquarters	www.weather.gov	Local forecasts to schedule outdoor activities. Click on map for desired NWS office.
NOAA 'All Hazards' Radio	http://www.nws.noaa.gov/nwr	Information on NOAA 'All Hazards' Radio. An excellent tool in weather safety.

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A fictional character 'Leon the Lightning Lion' was developed to teach lightning safety to children. This character was originally developed by the Lightning Safety Alliance. An interactive computer game using Leon was developed to teach lightning safety to children (Hodanish et al., 2008). A sequence of 17 situations is shown and the player answers if the situation is 'safe' or 'not safe' from lightning (Figure-8). Leon provides positive or negative feedback if the question is answered correctly or incorrectly, respectively. In particular, if an 'unsafe' location is chosen as 'safe', Leon is struck by lightning, reinforcing that a life-threatening decision was made (Figure-9). After each question, a brief explanation of the correct answer is provided. The percent correct is displayed at the end of game. This game has been very popular; even adults enjoy it.

Three posters based on Leon the Lightning Lion have been developed for lightning safety education. These posters help teach general lightning safety (Figure-10), swimming lightning safety (Figure-11), and lightning safety for outdoor sports (Figure-12). In addition, a coloring page version of the general lightning safety poster is available for children (Figure-13). Several other lightning safety posters featuring major sports stars and other general lightning safety awareness posters were also developed. These resources can be downloaded from the NOAA lightning safety website (www.lightningsafety.noss.gov).

Figure 8. A sample question from the Leon the Lightning Lion game.

Figure 9. A sample feedback from the Leon the Lightning Lion game. If you answer 'safe' to an 'unsafe' location or activity, Leon is struck by lightning and the correct answer with explanation is provided.

Figure 10. Leon the Lightning Lion poster for general lightning safety.

Figure 11. Leon the Lightning Lion poster for swimming lightning safety.

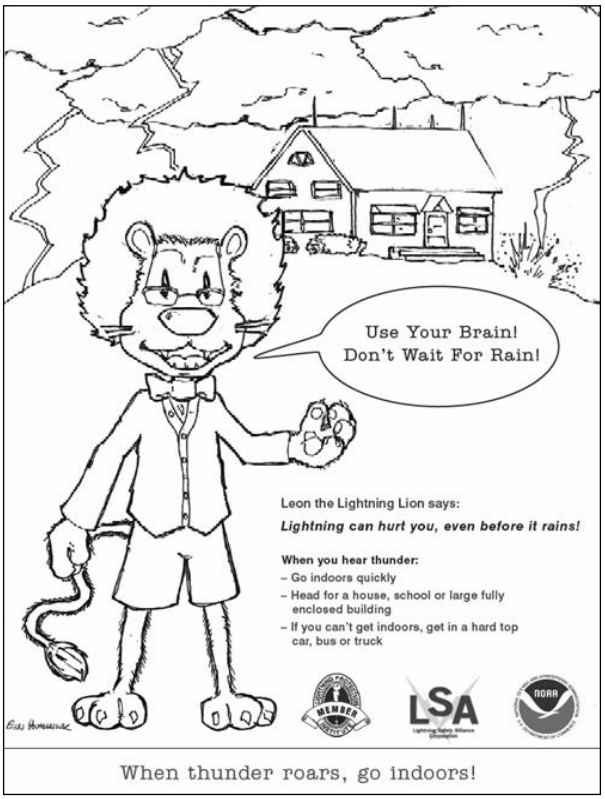

Figure 13. Leon the Lightning Lion coloring page.

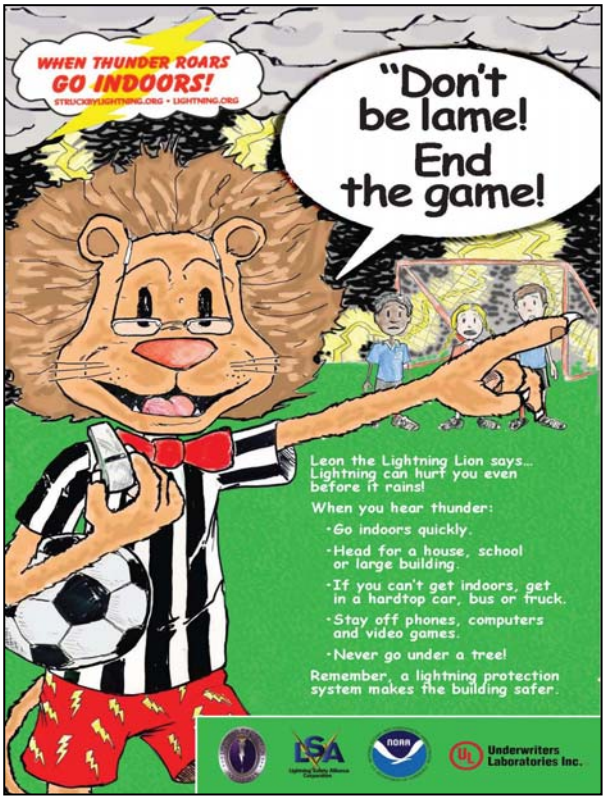

Figure 12. Leon the Lightning Lion poster for outdoor sports lightning safety.

5. Recent Updates In Lightning Safety

Recent updates in lightning safety consist of six topics: 1) upgraded safety from vehicles, 2) hearing thunder as cue to go to safety, 3) distribution of lightning fatalities by age, 4) don't teach last-second personal outdoor risk reduction to the general public, 5) Automated External Defibrillators in lightning safety first aid, and 6) pernicious lightning myths (Roeder, 2008b, 2008c). Each of those six topics is discussed in further detail below.

5.1 Upgraded Safety From Vehicles:

Lightning casualty reports for people inside vehicles with solid metal roofs and solid metal sides shows no electrical deaths and much reduced frequency and intensity of electrical injuries (Holle, 2008). This suggests that proper vehicles are as safe as large fully enclosed buildings with wiring and plumbing, if not even safer. As a result, the working group for the NOAA Lightning Safety Awareness Week (LSAW) upgraded the

safety provided by such vehicles from a '3' to a '9' on an arbitrary 10-point scale, the same as large fully enclosed buildings with wiring and plumbing (Table-5). While merely a subjective estimate of safety, this 10-point scale has proved useful in public education. Over the years, this 10 point has fallen into general disuse for unknown reasons. It is reintroduced here for use in public education.

Table 5.
Subjective 10-Point scale for lightning safety provided by various locations. Higher numbers are safer locations.

NO.	EXAMPLE
10	Lightning certified facility with extensive lightning protection and surge protection
9	• Large fully enclosed building with wiring and plumbing and obeying indoor safety guidance (typical house, school, store, office building, etc.) • Vehicle with solid metal roof and solid metal sides (typical car, bus, or truck, but **not** motorcycles, convertibles, bicycles, open or cloth covered vehicles, etc.)
8	None
7	None
6	None
5	None
4	None
3	None
2	None
1	None
0	Any Place Outside (some no-notice personal risk reduction is possible, but should only be used as a desperate last resort (see section-2.4))

5.2 Hearing Thunder As Cue To Go To Safety

The lightning safety community now recommends seeking a safe place when you hear thunder, rather than the previous guidance of the first '30' of the '30-30 Rule'. The first '30' in the '30-30 Rule' advised people to already be in a safe place when the time between lightning and its thunder was 30 seconds or less. This 30 seconds corresponds to a distance of about 6 miles, which is close enough for lightning to be a danger. Unfortunately, many people were remembering this as '<u>go</u>' to a safe place at this time, not '<u>be</u>' in a safe place. Some meteorologists even taught it that way. Therefore, the LSAW working group added reaction time into new guidance to help people know when to take action. The new cue is 'hearing thunder', especially for fast moving thunderstorms. The slogan 'When Thunder Roars, Go Indoors!' was developed to help teach this concept. This slogan has proven to be very useful. A second slogan was developed later for the second part of the '30-30 Rule' -- 'Half An Hour Since Thunder Roars, Now It's Safe To Go Outdoors!' This slogan is not as well developed and has not been as popular. Further refinement of this second slogan is required.

5.3 Distribution Of Lightning Fatalities By Age

An analysis of lightning fatalities by age in the U.S. were compiled for 1995-2006 from NOAA Storm Reports (www.weather.gov/os/hazstats.shtml), shown previously in Figure-5. The percent of lightning fatalities for each age bracket is normalized by its percentage of population from the 2000 U.S. census (www.census.gov), shown previously in Figure-6. The normalization produces a non-dimensional ratio, where '1' means the age bracket receives the number of fatalities expected for its population size.

These patterns are broadly consistent with an earlier study by Lushine et al. (2005) in Florida, except that study found that 10-19 year olds were at the largest risk. This study also found that the lightning fatalities by location or activity for youths were very different from adults, shown previously in Figure-3 and Figure-4, respectively. This led to matching slogans: 'Don't Be A Fool, Get Out Of The Pool!', 'Don't Be Lame, End The Game!', 'Don't Get Fried, Go Inside!', and others. The lightning fatality locations and activities for youths should be broadly applicable across the U.S., except the percentage from water activities may be smaller.

5.4 Don't Teach No-Notice Personal Outdoor Lightning Risk Reduction To The General Public:

Although the no-notice personal outdoor risk reduction process described previous can reduce lightning casualties by 47% ± 7% of taking no action (Roeder, 2008a), it still should not be taught to the general public for several reasons. First, while a reduction of just over half sounds like a significant reduction in risk, the likely consequences of a lightning strike are so severe, life-long debilitating injury or death, that the risk reduction is not enough. Adapting an analogy from Dr. Cooper, it is like being on a busy highway, but moving to the centerline, turning sideways, and waving your arms so drivers will see you. The risk is much reduced, but it is still too dangerous.

In addition, teaching no-notice outdoor risk reduction to general audiences is not an efficient use of training time. First, the process does not apply in well over 90% of the casualties, since nearby safe locations are available and people are much safer running there. Second, the instructions are complex and take a lot of time to teach, detracting from more beneficial training. Third, many people misremember the details and many more would likely misapply them under the stress of an imminent lightning threat. Fourth, many people showed considerable interest in this topic, which may detract from them remembering the more important parts of lightning safety. Fifth, this could undermine the main message of lightning safety -- 'No Place Outdoors Is Safe, When Thunderstorms Are In The Area!'

It is important to note that this advice only applies to level-4 of lightning safety, i.e. no-notice personal outdoor lightning risk reduction. Avoiding risky locations should still be practices in level-2, when people have to be outside when thunderstorms are in the area, but not immediately threatening. Also, no-notice personal outdoor lightning risk reduction may still be appropriate for groups that spend a lot of time far away from safe locations.

5.5 Automated External Defibrillators (AED) In First Aid:

All lightning deaths are from cardiac arrest or stopped breathing from the cardiac arrest. An AED will work on many of these cases and is much more effective than CPR. Thus, AEDs have been added to the recommended lightning first aid procedures. If an AED is not available, or does not activate because it detects the cardiac arrest is not from fibrillation, then resume CPR or rescue breathing.

5.6 Pernicious Lightning Myths:

Many myths that compromise lightning safety continue to persist (Roeder, 2007b). Indeed, 'myth busting' has proven to be one of the most useful techniques in teaching lightning safety. The most prevalent of these lightning myths are listed in Table-6. Several of these myths mislead people into thinking that some places outside may be safe under some situations, contrary to the fundamental principle of lightning safety -- 'No Place Outside Is Safe, When Thunderstorms Are In The Area!' (Roeder et al., 2001).

6. Lightning Protection

Lightning protection can improve lightning safety by decreasing the likelihood and intensity of indoor lightning shocks. There are two main forms of lightning protection: 1) lightning rods or air terminals (a network of one or more overhead wires), and 2) surge protection. In addition to increased personnel safety, lightning protection is important to facility protection, including avoiding fires and explosive damage to the building and electromechanical devices, and voltage surge damage to electronics, such as computers.

Table 6.
Pernicious lightning myths and their impact on lightning safety.

LIGHTNING MYTH	IMPACT ON LIGHTNING SAFETY
Rubber tires or rubber soled shoes protect you from lightning by insulating you from the ground	Can mislead people to not seek a safe place, or think that some unsafe locations are safe, e.g. convertibles, motorcycles, bicycles, etc.
Metal attracts lightning (variations include cell phones, i-pods, under wire bras, etc.)	Can mislead people to think wrongly that they are safe outside and thus avoid a safe place, or waste time shedding metal rather than rushing to safety. Cell phones and i-pods can interfere with people hearing thunder, a vital cue to seek safety.
Cell phones: - Attract lightning because they are metal - Attract lightning because the radio waves ionize the air and create a conducting path - Increase injuries because they are metal touching the skin, which channels more of the lightning current inside the body	Can mislead people to think that they are safe outside near thunderstorms if they don't have a cell phone. Can interfere with people hearing thunder, a vital cue to seek safety. Can mislead people outside not to use their cell phones to call for a ride when thunderstorms are threatening.
Lightning won't strike if it is not raining or cloudy	Can mislead people to think that they are safe outside when thunderstorms are in the area. About 1/3 of lightning strikes occur outside the rain.
'Cone Of Protection'	Can mislead people to think they are safe outside. Can mislead people to move closer to tall isolated objects, where lightning is more likely going to strike, increasing their risk.
Lightning never strikes the same place twice	Sometimes leads to erroneous advice to run to where lightning has just struck, rather than an appropriate safe place
A person who was just struck by lightning can electrocute you if touched	Misleads people to delay or not provide life saving first aid
Lay flat on the ground if lightning is imminent*	Misleads people to stay outside longer than they should when thunderstorms are in the area. Also increases risk from step voltage and ground streamers, which cause more casualties than direct lightning strikes.
Lightning is 100% deadly	Can mislead people to not apply first-aid
Running decreases the chances that lightning will strike you	Can mislead people to stay outside and not seek a safe place
A person struck by lightning will be turned into a burnt corpse (aka the crispy critter myth)	Can mislead people to not apply potentially life-saving first-aid
It won't happen to me	Misleads people to avoid practicing lightning safety

* The 'lightning crouch' provides more risk reduction than laying flat on the ground. However, teaching no-notice personal outdoor lightning risk reduction to the general public is no longer advocated (Roeder, 2008a).

6.1 Lightning Rods And Air Terminals

The function of lightning rods/air terminals is frequently misunderstood. They do not attract, repel, or prevent lightning, nor do they significantly increase or decrease the chances of a lightning strike. Rather they give a preferred point of attachment for lightning that was going to strike within a few tens of yards anyway. The intercepted lightning then follows a thick metal cable, the 'down conductor', to the grounding system where it is dissipated in the soil. The down conductor must have adequate cross sectional area to ensure low electrical impedance (inductance + resistance). Likewise, tight curves in the down conductor must be avoided (usually no less than eight inch radius of curvature) to reduce inductance impeding the flow of lightning current to the ground. Lightning rods/air terminals and the down conductors must be properly installed and maintained to work well. Corrosion maintenance is often required to ensure a clear conducting path to the ground. This is especially important in warm, moist, salty environments, such as throughout the

Southeast and Gulf States in the U.S. Installation is best left to professional electricians trained and experienced in these devices and the applicable standards.

People inside buildings with lightning rods must still obey the indoor lightning safety rules. The down conductor can induce dangerous secondary electric currents in wiring or metal pipes nearby in roofs or walls.

Good lightning protection also requires a single point ground be used (aka common ground) to ensure an equipotential environment. All grounded conductors, such as electric power grounds, phone and cable grounds, electrical conduits, metallic plumbing and structural steel, should be conductively tied to the lightning protection ground at a single physical point. Even if a common ground is used, but not grounded at a single physical point, strong voltages can be induced across the conductors due to the very rapid rise times in lightning. However, with single point grounds, when lightning momentarily raises the building's electrical potential to as much as several megavolts, all points rise together, and no hazardous or damaging potential differences and transient electrical currents are created. This is especially important in large facilities with multiple conducting systems, such as schools.

Lightning protection works only as well as its grounding system. Getting a good electrical ground into soil can be surprisingly difficult. Most lightning protection standards require only low electrical resistance. However, the total impedance is what really counts. Impedance consists of both a time-varying inductance term and a non-varying resistance term. Since lightning has very fast rise times, the inductance term is very important. Unfortunately, the inductance term is often ignored in lightning grounding systems. Increasing the surface area making solid contact with the soil can usually lower impedance of grounding systems. One typical technique is driving metal pipes deep into the ground. One of the best solutions is laying the down conductor into shallow troughs of conducting concrete (concrete with carbon graphite fibers mixed in) extending outward from the site being protective. Not only does this greatly increase the surface area touching the soil for reduced impedance, but it also takes advantage of lightning's natural tendency to spread outward near the surface of the soil (the 'Skin Effect', the time varying equivalent of the better known D.C. 'Faraday Cage'). However, don't have the down conductor pass through or near where people will be, e.g. sidewalks, parking lots, etc. If they are there when the lightning is being discharged into the soil, they can be injured or killed. The low D.C. resistance in most standards does serve an important purpose since some lightning has a relatively long-lived continuing current after the rapidly varying currents. This is especially true for strong positive polarity lightning, which can be more than tens times as powerful and damaging as normal negative polarity lightning.

Unfortunately, alternative devices claiming to work much better than lightning rods are being aggressively marketed. These devices are known generically as Early Streamer Emission (ESE) and Charge Dissipation (CD) devices, but are marketed under continuously varying names. Independent expert panels and empirical evidence soundly reject these devices, finding that they work no better than traditional lightning rods. Thus, the extra cost of these systems is not justified. While you may believe you are saving money, in reality you actually providing inadequate protection for your facility. In general, beware of devices that claim to intercept lightning over a larger area than traditional lightning rods or prevent/reduce lightning.

Lightning protection can help guard against most of the dangerous and damaging electric current from a lightning strike to the building, by preventing most of the electricity from entering inside the building. However, it provides no protection from lightning striking external conducting paths leading inside, such as telephone wires, power lines, and plumbing. Surge protection is required to help mitigate those hazards.

6.2 Surge Protection

Surge protection against lightning is extremely challenging, given lightning's very high current (~tens of thousands of amps) and very rapid rise times (~milliseconds). No single device can totally provide lightning surge protection, so a series of devices in the proper sequence is best. Gas discharge tubes are a good first line of defense and can divert much of the lightning current to the electrical ground. However, they are relatively slow devices, so much of the early very high frequency current is passed through them. Bulk electronic components (capacitors, resistors, and inductors) can make low pass filters that can dissipate much of the high frequency current, passing only a little current at the highest frequencies. These make a good second line of defense. High-speed microelectronics such as Metal Oxide Varister (MOV) devices can eliminate the remaining small power high frequency currents. These devices can only handle small currents and must come last in the series of lightning surge protectors. Some manufacturers claim more recent MOVs can handle the power of lightning and are all that is required for lightning surge protection. Also, MOVs can degrade after large voltage spikes are even over time. Multi-level surge protection is especially important for delicate electronics, such as school computer labs. Modern electronics are extremely sensitive to electric surges—even just a few volts of sudden over-voltage can destroy micro-integrated circuits. Don't forget to protect computer modems, which seem to be especially susceptible to electrical surge damage, either because phone lines transmit surges more often and/or an innate sensitivity.

In the U.S., many electric power companies often offer reliable lightning surge protection at reasonable cost. However, most of these devices provide only the first-line protection that protects electromechanical devices and improve personnel safety. Further surge protection for delicate electronics will likely be needed. Also, these devices often only guard against incoming surges on power lines. They may not guard against surges from other paths, such as telephone wires and plumbing.

As with lightning protection, surge protection works only as well as its grounding system. Grounding systems must also ensure that a common ground is used, to avoid potentially destructive electrical voltages developing in the system. This means all the grounding systems, such as the lightning protection ground, electric power ground, phone and cable grounds, and plumbing must be connected electrically to each other at some point. These points of electrical connection must be physically close to each other to avoid transient voltages across the system due to the fast rise time of lightning. Common grounds are especially important in large facilities with multiple conducting systems, such as schools.

Unfortunately, some vendors market surge protectors as effective against lightning that cannot handle either its power or fast rise times. They may advertise insurance to cover damage, but the insurance company declares bankruptcy when a large claim is filed. Alternatively, they may cite Underwriters Laboratory approval, but that means the device isn't dangerous, not that it is effective.

Uninterruptable Power Source (UPS) should be used for electrical devices that are sensitive to power interruptions.

7. Research Requirements for Improved Lightning Safety

There are 30 topics requiring research to improve lightning safety (Roeder, 2009a; 2009b). These research topics are listed in rough priority order in Table-7.

Table 7
Research required to improve lightning safety.

No.	Topic
1	Distance thunder can be heard vs. terrain type, wind, buildings, and background noise (Fleagle, 1949; Veenema, 1920)
2	Utility of hearing thunder as cue to seek safety
3	Continued analysis of lightning casualty demographics and their societal shifts
4	Translate lightning safety education materials into Spanish and other languages, e.g. new NOAA brochure
5	Frequency of cloud-to-ground lightning (CG-Ltg) outside of rain for different types of thunderstorms (Roeder, 2007b)
6	Frequency of CG-Ltg outside of cloud for different types of thunderstorms (Roeder, 2007b)
7	Automated lightning warnings from National Weather Service (Roeder and Pinder, 1998)
8	Best fit curve with error bars of declining annual lightning death rate, and expected death total by day of the year, adjusted for falling annual rate
9	Distribution of lightning vs. distance across and along anvil clouds (Roeder, 2008b, 2008c)
10	Frequency and distance distribution of “bolts from the blue” and conditions where they occur (Roeder, 2008b, 2008c)
11	Utility of lightning aloft in lightning safety under different weather conditions, e.g. post squall line stratiform rain
12	Frequency, distance, and lead-times provided by lightning aloft and CG-Ltg vs. when lightning casualties occurred (Lengyel et al., 2005; Holle at al., 1993)
13	Objectively rate the relative safety provided by houses with/without lightning protection, and obeying/not obeying indoor safety rules
14	Objectively rate the relative safety provided by different types of vehicles and relative to being indoors
15	Objective and independent evaluation of hand-held lightning detectors
16	Objective and independent evaluation of commercial lightning prediction systems
17	Evaluate lightning safety of indoor pools
18	Recommendations for developing countries (Holle and Lopez, 2003)
19	Distance that ground streamers and step voltages can cause death and injury
20	Distance that lightning can cause casualties via conducting paths
21	Refine ratio and severity of lightning injuries vs. lightning deaths
22	Improve the percentages of lightning casualties vs. the five lightning casualty mechanisms (Cooper at al., 2008; Roeder, 2009a, 2009b, 2008b, 2008c)
23	Estimate the frequency that precursors to imminent lightning are observed with sufficient lead-time to take action (Cooper at al., 2008; Roeder, 2009a, 2009b, 2008b, 2008c)
24	Refine estimate of the frequency that safe locations are available to lightning victims (Roeder, 2009a, 2009b, 2008b, 2008c)
25	Update estimate of under reporting of lightning deaths and injuries (Richey et al., 2007) (Cherington et al., 1999) (Lopez et al., 1993) (Mogil et al., 1977)
26	Analyze completeness of lightning casualties in NOAA Storm Reports (Richey et al., 2007)
27	Estimate utility of no-notice outdoor lightning risk reduction under conditions other than an open field (Roeder, 2009a, 2009b, 2008b, 2008c)
28	Professional communicators refine lightning safety slogans, especially ‘Half An Hour Since Thunder Roars, Now It’s Safe To Go Outdoors!’
29	Quantify the role of the composition of an object in changing the probability of being struck, chance of death or injury, and severity of injury (Roeder, 2007b)
30	Develop semi-portable protection for camp sites and very lightweight portable protection for hikers

8. Summary:

Lightning is the second leading of storm deaths in the U.S. and inflicts lifelong debilitating injury on many more than it kills. Fortunately, lightning safety in the U.S. is easy, quick, effective, and inexpensive. Public education is the key. However, lightning safety is inconvenient, so people need to be diligent in following the recommended guidelines consistently. Lightning is also a significant source of weather casualties in many other countries throughout the world.

A 5-level method for teaching lightning safety was presented. This 5-level method includes several recent improvements to lightning safety. The following three slogans provide an easy-to-remember summary of lightning safety:

- **No** Place Is Safe,
  When Thunderstorms Are In The Area!
- When Thunder Roars, Go Indoors!
- Half An Hour Since Thunder Roars,
  Now It's Safe To Go Outdoors!

Other advice on teaching lightning safety was presented, including pernicious myths that detract from proper lightning safety. The 10-point scale ranking locations for lightning safety was reintroduced. In addition, research required to improve lightning safety further was discussed. Finally, lightning protection was briefly covered.

9. Disclaimer:

This paper is presented for informational purposes only and no guarantee of lightning safety is stated or implied by the recommended procedures.

10. Acknowledgments

The author is deeply indebted to many mentors since becoming active in lightning safety public education in 1998. Three especially noteworthy mentors are Ron Holle of Holle Meteorology & Photography (formerly National Severe Storm Laboratory), Mary Ann Cooper, M.D., retired (formerly University of Illinois at Chicago), and Rich Kithil of the National Lightning Safety Institute.

Dr. Carlos Mata modeled the reduction of direct strikes due to the 'lightning crouch' that was used to estimate part of the risk reduction provided by no-notice personal outdoor risk reduction (Mata and Rokov, 2008).

Dr. Mary Ann Cooper, M.D. retired (formerly University of Illinois at Chicago) advised on the first-aid section in an earlier version of this paper.

Mr. Terry Willingham, chairperson of the NASA Kennedy Space Center Lightning Safety Assessment Committee, reviewed the section on lightning protection section in an earlier version of this paper.

11. 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, *11th Conference on Applied Climatology*, 10-15 Jan 99, 379-380

Cooper, M.A., R. L. Holle, and A. Andrews, 2008: Distribution of lightning injury mechanisms, *20th International Lightning Detection Conference*, 22-23 Apr 08, 4 pp.

Cooper, M. A., and R.L. Holle, 2007: Casualties from lightning involving motorcycles, *International Conference on Lightning and Static Electricity*, Paper IC07-KM02, 28-31 Aug 07, 6 pp.

Cooper, M. A., 1995: Emergent care of lightning and electrical injuries, *Seminars in Neurology*, Vol. 15, No. 3, Sep 95, 268-278

Curran, E. B., R. L. Holle, and R. E. Lopez, 2000: Lightning casualties and damages in the United States from 1959 to 1994, *Journal of Climate*, Vol. 13, 3448-3453

Fleagle, R. G., 1949: The audibility of thunder, *Journal of the Acoustical Society America*, Vol. **21**: Issue 4, 411-412

Hodanish, S. J., K. Torgerson, J. S. Jensenius, M. A. Cooper MD, M. Utley, and W. P. Roeder, 2008: Leon the lightning safety lion says: "When thunder roars, go indoors!" - NOAA's efforts

regarding children's lightning safety, *3rd Conference on Meteorological Applications of Lightning Data*, 20-24 Jan 08, 4 pp.

Holle, R. L., 2008: Lightning-caused deaths and injuries in the vicinity of vehicles, *3rd Conference on Meteorological Applications of Lightning Data*, 19-23 Jan 08, 10 pp.

Holle, R. L., 2005a: Lightning-caused recreation deaths and injuries, *14th Symposium on Education, American Meteorological Society*, 9-13 Jan 05, 6 pp.

Holle, R. L., 2005b: Lightning-caused deaths and injuries during hiking and mountain climbing, *International Conference on Lightning and Static Electricity*, 20-22 Sep 05, Paper KMP-33, 9 pp.

Holle, R. L., M. Murphy, and R.E. Lopez, 2003: Distances and times between cloud-to-ground flashes in a storm, *International Conference on Lightning and Static Electricity*, Paper 103-79 KMI, 8 pp.

Holle, R.L., and R.E. Lopez, 2003: A comparison of current lightning death rates in the U.S. with other locations and times, *International Conference on Lightning and Static Electricity*, 16-18 Sep 03, Paper 103-34 KMS, 7 pp.

Holle, R. L., R. E. Lopez, and C. Zimmermann, 1999: Updated recommendations for lightning safety, *Bulletin of the American Meteorological Society*, Vol. 80, No. 10, Oct 99, 2035-2041

Holle, R.L., R.E. López, R. Ortiz, C.H. Paxton, D.M. Decker, and D.L. Smith, 1993: The local meteorological environment of lightning casualties in central Florida, *17th Conference on Severe Local Storms and Conference on Atmospheric Electricity*, 4-8 Oct 93, 779-784

Jensenius, J. S., D. B. Franklin, and S. Hodanish, 2008: Lightning kills—play it safe NOAA's efforts to educate the public on the dangers of lightning safety, *3rd Conference on Meteorological Applications of Lightning Data*, 19-23 Jan 08, Paper 5.2, 5 pp.

Lengyel, M. M., H. E. Brooks, R. E. Holle, and M. A. Cooper, 2005: Lightning casualties and their proximity to cloud-to-ground flashes, *14th Symposium on Education, American Meteorological Society*, Paper P1.35, 9-13 Jan 05, 7 pp.

Lopez, R. E., T. A. Heitkamp, M. Boyson, M. Cherington, and K. Langford, 1993: The underreporting of lightning injuries and deaths in Colorado, *Bulletin of the American Meteorological Society*, **74**, 2171-2178

Lushine, J. B., W. P. Roeder, and R. J. Vavrek, 2005: Lightning safety for schools: An update, *14th Symposium on Education*, 9-13 Jan 05, 10 pp.

Mata, C. T. and V. A. Rakov, 2008: Evaluation of lightning incidence to elements of a complex structure: A Monte Carlo approach, *International Conference on Grounding and Earthing and 3rd International Conference on Lightning Physics and Effects*, 16-20 Nov 08, 4 pp.

McAleenan, M., 2004: *Personal Communication*, 45th Weather Squadron, Patrick Air Force Base, FL, michael.mcaleenan@patrick.af.mil

McNamara, T. M., 2002: The Horizontal Extent of cloud-to-ground lightning over the Kennedy Space Center, *M. S. thesis Air Force Institute of Technology*, AFIT/GM/ENP/02M-06, Mar 02, 114 pp.

Mogil, H.M., M. Rush, and M. Kutka, 1977: Lightning--An update, *10th Conference on Severe Local Storms*, 226-230

Murphy M., A. Pifer, K. Cummins, R. Pyle, and J. Bramer, 2002: The 2002 upgrade of the U.S. NLDN, *17th International Lightning Detection Conference*, 16-18 Oct 02, 4 pp.

Nelson, L. A., 2002: Synthesis of 3-dimensional lightning data and weather radar data to determine the distance that naturally occurring lightning travels from thunderstorms, *M.S. thesis Air Force Institute of Technology*, AFIT/GM/ENP/02M-07, Mar 02, 85 pp.

NOAA, 2009: Natural Hazards Statistics, NOAA, National Weather Service, *Office*

of Climate, Water, and Weather Services, 1325 East West Highway, Silver Spring, MD 20910, www.weather.gov/os/hazstats.shtml

NOAA, 2007: Natural Hazards Statistics, NOAA, National Weather Service, *Office of Climate, Water, and Weather Services*, 1325 East West Highway, Silver Spring, MD 20910, www.nws.noaa.gov/om/hazstats/images/67years.pdf, 1 pp.

Richey, S., R. L. Holle, and M.A. Cooper, 2007: A comparison of three data collection methods for reporting of lightning fatalities in Florida from 1995 to 2004, *International Conference on Lightning and Static Electricity 2007*, 28-31 Aug 07, Paper IC07-KM01, 4 pp.

Roeder, W. P., 2009a: Research requirements for better lightning safety, *34th National Weather Association Annual Meeting*, 18-22 Oct 09, 1 pp.

Roeder, W. P., 2009b: Research required to improve lightning safety, *4th Conference on Meteorological Applications of Lightning Data*, 11-15 Jan 09, Paper JP1.1, 5 pp

Roeder, W. P., 2008a: An analysis of the effectiveness of short notice outdoor lightning risk reduction and comments on why it should not be taught, *3rd Conference on Meteorological Applications of Lightning Data*, 19-23 Jan 08, Paper 5.3, 7 pp.

Roeder, W. P., 2008b: Recent changes in lightning safety, *3rd Conference on Meteorological Applications of Lightning Data*, 19-23 Jan 08, Paper P2.14, 5 pp.

Roeder, W. P., 2008c: Recent updates in lightning safety, *20th International Lightning Detection Conf.*, 21-22 Apr 08, 6 pp.

Roeder, W. P., 2007a: Teaching lightning safety—A five level method, *International Conference on Lightning and Static Electricity*, Paper IC07-ABKM05, 28-31 Aug 07, 7 pp.

Roeder, W. P., 2007b: Pernicious lightning myths, *International Conference on Lightning and Static Electricity*, Paper IC07-ABKM06, 28-31 Aug 07, 5 pp.

Roeder, W. P., R. J. Vavrek, F. C. Brody, J. T. Madura, and D. E. Harms, 2001: Lightning safety for schools, *10th Symposium on Education*, 14-19 Jan 01, 89-92

Roeder, W. P., and C. S. Pinder, 1998: Lightning forecasting empirical techniques for ventral Florida in support of America's space program, *16th Conference on Weather Analysis and Forecasting*, 11-16 Jan 98, 475-477

Veenema, L. C., 1920: The audibility of thunder, *Monthly Weather Review*, Vol. **48**: Issue 3, 162

Weems, J.W., C. S. Pinder, W. P. Roeder, and B. F. Boyd, 2001: Lightning Watch And Warning Support To Spacelift Operations, *18th Conference on Weather Analysis and Forecasting*, 30 Jul-2 Aug 01, 301-305