1.2 Communicating Lightning Safety Effectively

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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 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 prevented easily, quickly, and cheaply. Public education is the key. However, that public education needs to be communicated effectively.

2. Communicating Lightning Safety Effectively

Lightning safety requires the same two basic elements as any public education effort. First, the public must be motivated to learn the information. Second, the information taught must be effective. In addition, the message must be clear and easy to remember in a stressful situation such as when lightning threatens. As in most communications, tailoring the message to the audience is the key.

2.1 Motivating the Public

Motivating the public to learn lightning safety is easy. Lightning is the second leading cause of storm deaths in the U.S., only floods kill more (NOAA, 2009). Lightning kills more than tornadoes or hurricanes in the U.S. (Figure-1). Lightning also inflicts life-long debilitating injury on many more than it kills (Cooper, 1995). The outcome of the injury and its impacts on a family can have high impact when included in educational efforts. Location, timing, lightning casualty demographics, local application, and other motivational factors can also be used to increase the interest in lightning safety.

2.1.1 Location

The average lightning flash density across the CONUS can be used to increase interest in lightning safety education and indicate where the risk is highest (Figure-2). Most of the lightning in the U.S. occurs in the Southeast U.S., Gulf States, Mississippi and Ohio River Valleys, and the Front Range of the Rocky Mountains. However, no place in the U.S. is safe from lightning.

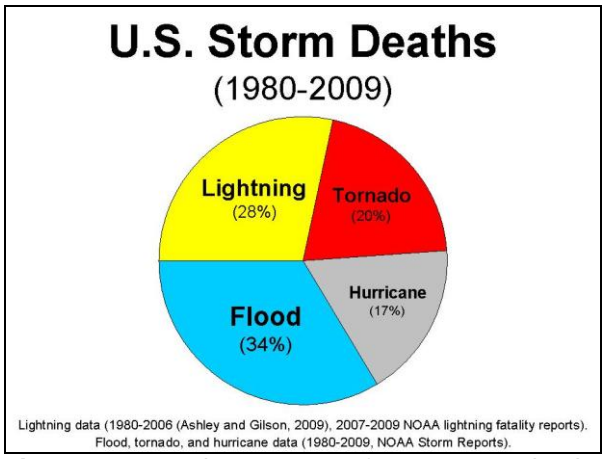


Figure 1. Weather causes of U.S. storm deaths (1980-2009). The lightning data for 1980-2006 are from Ashley and Gilson (2009), 2007-2009 are from NOAA 2010a). The lightning data account for underreporting, which has been significant in the past (Lopez et al., 1993). Underreporting of the deaths from the other weather phenomena are not accounted for, presumably since they're much better recorded. The flood, tornado, and hurricane data are from NOAA Storm Reports (2010b).

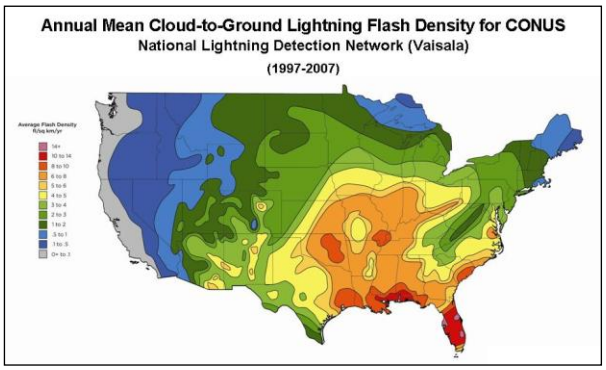
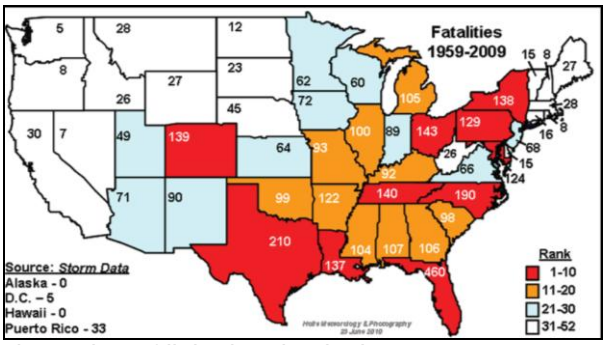


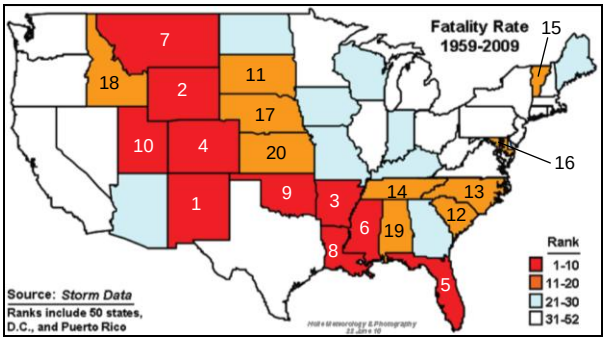
Figure 2. Average U.S. cloud to ground lightning flash density (1997-2007) from the National Lightning Detection Network. The highest flash densities are in the Southeast U.S., Gulf States, Mississippi and Ohio River Valleys, and the Front Range of the Rocky Mountains. However, no place in the U.S. is safe from lightning. The graphic in this figure is from Vaisala, Inc.

The distribution of lightning deaths by state (Figure-3a) can also be used to generate interest in lightning safety and guide where lightning safety education is most needed. For example, Florida, Texas, and North Carolina are the top three states for lightning deaths in the U.S., respectively. Likewise, the per capita rank of a state (Figure-3b) can also be used to generate interest and guide where lightning safety education would be most effective. New Mexico, Wyoming, and Arkansas are the top three states for per capita lightning deaths in the U.S., respectively.

In many states, lightning is the leading source of storm deaths, which is especially useful in motivating lightning safety education. The best example is Florida where lightning is the leading source deaths from all types of weather, not just storm weather, and kills more than nearly all other weather combined (Figure-4).



a) Number of lightning deaths by state.



b) Rank of lightning per capita deaths by state.

Figure 3. Lightning deaths in the U.S. by state (1959-2009) (Holle, 2011).

The shift of the per capita lighting deaths away from the highest flash densities in the U.S. to the Rocky Mountain states is notable. The lightning fatality rate in an area is due to the lightning flash density, population density, and amount of behavior that exposes the population to lightning. Using per capita fatalities accounts for population, so the shift is due to behavior, presumably the amount of recreation and outdoor work far from places that are safe from lightning. This suggests that lightning safety education can be effective through influencing behavior.

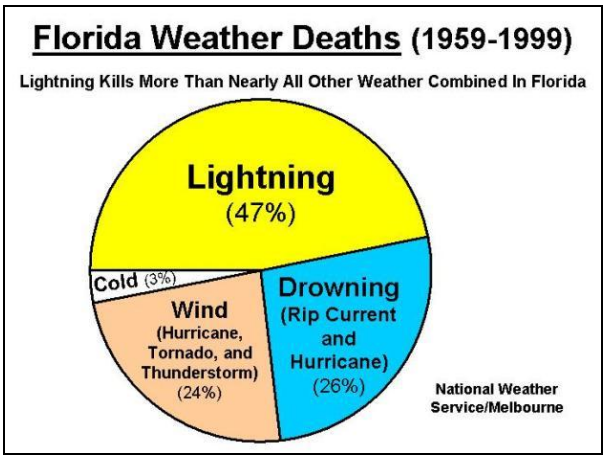


Figure 4. Relative contribution of weather phenomena to deaths in Florida. Lightning kills more than nearly all other weather combined in Florida.

Rather than analyzing lightning casualties by state as has been done in the past, Ashley and Gilson (2009) analyzed the data on a grid across the U.S. (Figure-5). The new analysis confirmed some previously recognized patterns of lightning fatalities and added new detail, e.g. maximums in Florida, along the Gulf coast, through the Mississippi River and Ohio River Valleys, and along the Front Range of the Rocky Mountains. The maximum in North Carolina was suspected but not widely recognized. The strong maximum from New York City to Washington D.C. was not previously recognized and pinpoints a new need for lightning safety education in that area. These data were not normalized for population density nor flash density, which presumably would confirm areas with disproportionate risky behavior, such as New Mexico, Wyoming, Colorado, and throughout the Rocky Mountain states.

2.1.2 Timing

Lightning safety is best taught just before the start of the local lightning season. For the U.S. as a whole, over 3/4 (77.5%) of the lightning occurs in just 1/3 of the year (May–August) (Figure-6) (Holle and Cummins, 2010). Some regions have different lightning seasons, which can be used to time lightning safety education to make it more effective. For example, most lightning in Arizona and the surrounding states occurs in July-August.

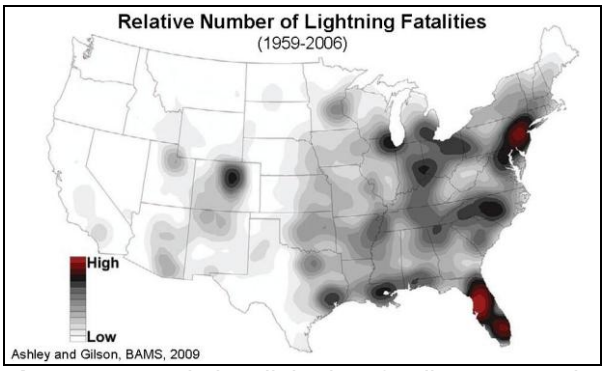


Figure 5. Relative lightning fatality across the CONUS 1959-2006 based on gridded analysis (Ashley and Gilson, 2009). Although more detail is shown, the results are roughly with consistent with previous state-based analysis showing a strong maximum in Florida, along the Gulf coast, throughout the Mississippi and Ohio River Valley, and along the front range of the Rocky Mountains. The maximum in North Carolina was suspected but not widely recognized. The strong maximum along the New York City to Washington D.C. metropolitan corridor was not previously known. Figure is from Ashley and Gilson (2009).

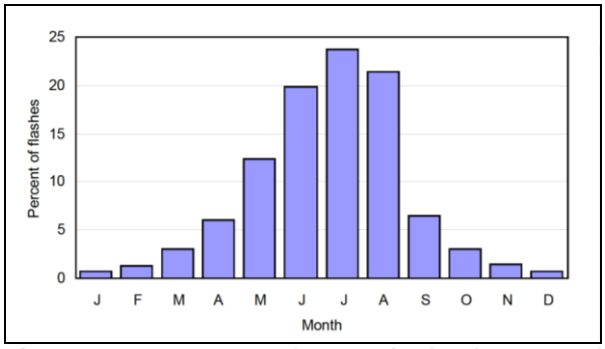


Figure 6. Percent of annual cloud-to-ground lightning flashes by month for the CONUS and adjacent areas from the NLDN. 77.5% of the lightning occurs during May-August. (Holle and Cummins, 2010).

Another opportune time to teach lightning safety is just before an outbreak of lightning. For example, the Seattle area has very little lightning compared to the rest of the U.S. (Figure-2), even during the summer. If lightning were predicted for the next day(s), especially over the mountains, that would be an excellent time to increase of awareness of lightning as a weather hazard and remind them of the lightning safety procedures.

Another good time to teach lightning safety is just before a major event like a holiday weekend or large outdoor sports or entertainment event during the summer. Independence Day is especially worrisome as a holiday with lots of outdoor activity during the peak of lightning season.

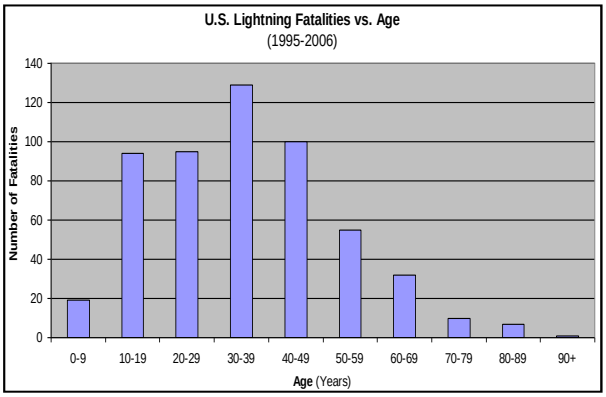
Yet another good time to teach lightning safety is immediately after a lightning casualty is reported by the media. The wider the coverage and the more the public interest in the story, the more useful and the longer the story can be used to improve the effectiveness of lightning safety. The NOAA lightning safety website is rapidly updated with media reports of lightning casualties, usually within 1-2 business days of the report (www.lightningsafety.noaa.gov). These reports are useful in making lightning safety education more topical for specific audiences.

Finally, conducting lightning safety education in conjunction with the national Lightning Safety Awareness Week is recommended. This event has been held annually by the National Weather Service during the last week of June since 2001 (Jensenius et al., 2008). More details on Lightning Safety Awareness Week and many resources for teaching lightning safety are at the NOAA website on this topic (www.lightningsafety.noaa.gov).

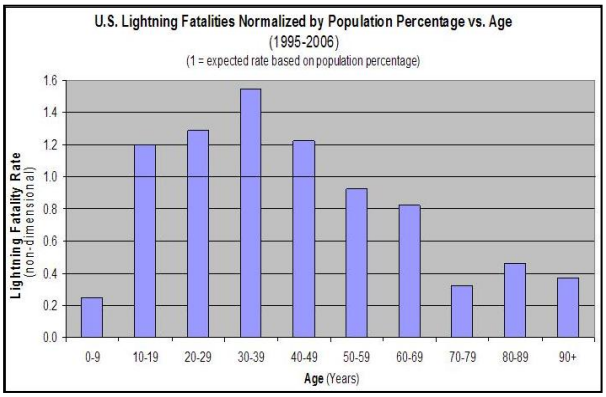
2.1.3 Lightning Casualty Demographics

Lightning casualty demographics are extremely useful in tailoring lightning safety education. The distributions of lightning deaths by age and normalized by population are in Figure-7a and Figure-7b, respectively. The largest jump in per capita lightning deaths is from children 0-9 years old to youths 10-19 years old. This is presumed to be due to youths doing more outdoor activities without adult supervision along with a lack of awareness of the lightning threat and/or more risk taking behavior in adolescence. Since children are easier to educate than youths and adults, emphasizing children's education is one of the most effective strategies for teaching lightning safety—teach them while they're young before they develop bad lightning safety habits. Several tools for teaching lightning safety to children have been developed and will be discussed in section-3.5.

The distribution of lightning deaths by gender strongly suggests the need to emphasize lightning safety education to males (Figure-8). The approximately 5:1 ratio of male to female lightning deaths has been surprisingly persistent across many locations, many time periods in the U.S., and even outside the U.S. (Pinto et al., 2010).



a) Lightning fatalities in the U.S. by age.



b) Lightning fatalities in the U.S. by age normalized by population. A value of 1 indicates an average per capita death rate.

Figure 7. Lightning fatalities in the U.S. by age from NOAA Storm Reports (NOAA, 2007).

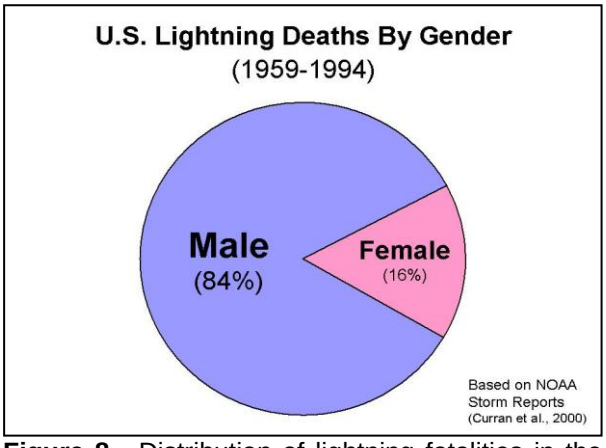


Figure 8. Distribution of lightning fatalities in the U.S. by gender. (Curran et al., 2000).

The percentage of lightning deaths in the U.S. due to various activities and locations in the recent past is shown in Figure-9. More recent studies indicate a shift towards more lightning deaths during outdoor recreation (Holle, 2005a, 2005b) and other outdoor leisure activities. Some of these activities are at home or routine, e.g. gardening, yard work, coming home from school, which may contribute to a false sense of safety and make people complacent about following the lightning safety guidelines.

The trend toward a smaller percentage of indoor lightning fatalities and a larger percentage of outdoor recreation lightning fatalities has been observed over more than a century in the United States (Figure-10) (Holle et al., 2005). An excellent example of the need to tailor the lightning safety message is suggested by Figure-11. The activities and locations for lightning deaths for youths in Florida clearly show a need for more emphasis on water related activities than for the state as a whole (Figure-9).

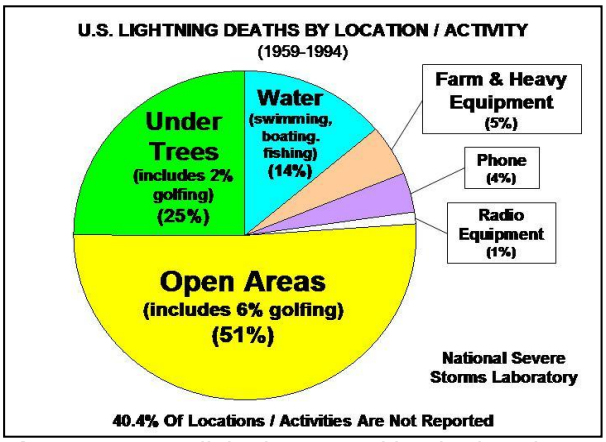


Figure 9. U.S. lightning casualties by location or activity (Curran et al., 2000).

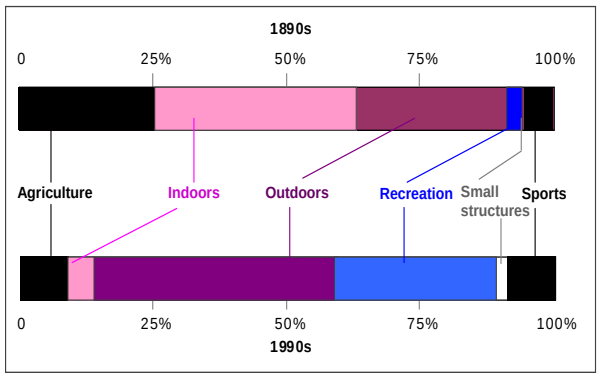


Figure 10. Comparison of the percentage of locations and activities of lightning deaths in the U.S. from the 1890s and the 1990s associated with U.S. lightning casualties by location or activity. Note the large increase of percentage of lightning deaths during recreation. Also of interest is the large decrease of percentage of lightning deaths while indoors. The figure is from Holle et al. (2005).

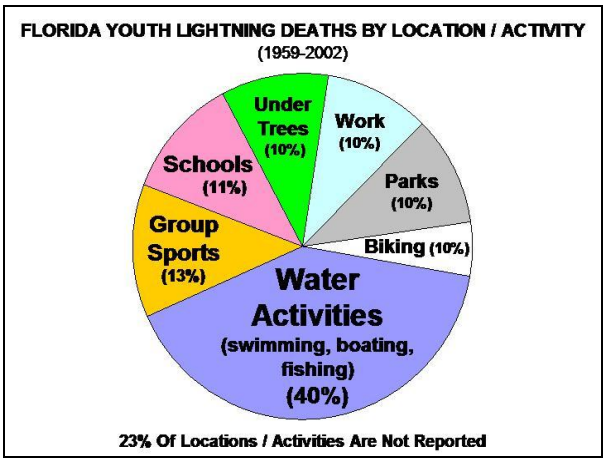


Figure 11. Location/activity of youth lightning fatalities in Florida (Lushine et al., 2005).

2.1.4 Local Tailoring

Tailoring the lightning safety message to the local area can increase interest in the training. For example, in the Seattle example in section 2.1.2, where a lightning outbreak is predicted the next day over the mountains, warning hikers and campers can increase the public's interest. Likewise, connecting the lightning safety message to a major event like a holiday weekend, or large outdoor sports or entertainment event can be useful.

2.1.5 Other Motivational Factors

People must be responsible for their own lightning safety. This is especially true since the National Weather Service (NWS) does not issue weather watches or warnings for lightning as they do for severe weather such as tornadoes. This self reliant nature of lightning safety can motivate some people. Unfortunately, it can also discomfort some people who prefer objective decision cues or direction from authorities to take action.

Parents, coaches, teachers, and other adults supervising children are responsible for the lightning safety of those in their charge. This profound responsibility can be very motivational, especially given the large chance of life-long debilitating injury from lightning, which is that much more terrible when the survivors are children since they have that much life in which to suffer.

2.2 Effective Information

To be effective in lightning safety education, the information must be correct, consistent, credible, easy to use, easy to remember, and interesting to learn. Just as motivating interest in lightning safety is easy (section-2.1), using effective lightning safety information is also easy. The key is to make the design and content as fact-based as possible.

Much progress has been made on lightning safety over the past two decades and strong consensus exists within the lightning safety community on most of the details on the correct information. Some recent updates to lightning safety are discussed in Roeder (2008b, 2008c). That strong consensus and consistency in teaching that information is essential to credibility. Unfortunately, some incorrect or out of date information is still presented by well meaning but misinformed people and media. Nevertheless, their efforts can still serve a useful purpose by increasing lightning safety awareness. While technical precision is laudatory, many of these incorrect points are minor technicalities and do not make significant difference in behavior or outcome so that corrective efforts are better spent where they will more effective.

To be the most effective, lightning safety information must be interesting to learn, easy to remember, and easy to use. If the lightning safety information is not interesting to learn, people will not gain the necessary information to practice good lightning safety. If the lightning safety information is not easy to remember, people will not retain the necessary information to practice good lightning safety, even if they did learn it. If the lightning safety information is not easy to use, people will not practice good lightning safety, even if they learned it and remembered it.

3. Tools For Teaching Lightning Safety

Several tools have been developed that incorporate the principles that have proven to be effective in teaching lightning safety. Six of the best tools are: 1) the 5-levels of lightning safety, 2) slogans, 3) myth busting, 4) enlisting the media, 5) teaching children, and 6) lightning survivor testimonials.

3.1 The 5-levels of Lightning Safety

The 5-levels of lightning safety are consistent with the current consensus on lightning safety, are easy to remember, and easy to use (Roeder, 2007a, 2003). Several refinements to lightning safety have been made in recent years (Roeder, 2008b, 2008c) (Table-1). The 5-levels of lightning safety include these refinements. The 5-levels are briefly summarized in Table-2. The fundamental principle of lightning safety is:

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

TABLE 1.
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 personal backcountry 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

TABLE 2.
Quick Reference For The Five Levels Of Lightning Safety

Fundamental Principle: **NO** place outside is safe, when thunderstorms are in the area!

	LEVEL	BRIEF DESCRIPTION
Best to Worst ↓	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 backcountry lightning risk reduction, including the 'lightning crouch' is no longer advocated for general audiences (Roeder, 2008a), but it may be useful 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.

3.1.1 Level-1 Scheduling Outdoor Activities

In any safety procedure, avoiding the risk is best. Outdoor activities should be scheduled to avoid the lightning threat. People should be taught to plan ahead; use the weather forecast and know their 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.

3.1.2 Level-2: Know When And Where To Go When Lightning Threatens

Knowing when and where to go when lightning threatens is a key component in lightning safety.

3.1.2.1 When To Go For Safety

Watch the skies for approaching or locally developing threatening clouds and listen for thunder. When thunder is heard, people should quickly go to a place that is safe from lightning. They should 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 may be especially important since most people seem to focus on when to go to a safe place, rather than when it is safe to leave that place, and a small older study suggested that half or more of lightning casualties occurred after the storm moved away or dissipated (Holle et al., 1993). This guidance is consistent with the lightning warning process used by America's space program in Florida (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' directed people 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 mean they should start moving to a safe place at the 30 second threshold. However, the '30-30 Rule' actually meant people should already be in the safe place by the 30 second threshold.

Despite strong attempts to correct this misinterpretation, and the illogical implication that all situations need the same amount of 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, may allow only a few minutes of lead-time to get to safety. 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.

A key weakness of listening for thunder is that it may not be audible in noisy environments or in mountainous locations with intervening terrain. Although the lightning safety community no longer teaches the '30-30 Rule', variations of it are still used in many recreational, industrial, and public safety situations. Users of the 30-30 Rule should ensure the correct wording is employed. Recent research suggests lightning strikes at distances too short for thunder to provide sufficient warning in almost half the events (Lengyel et al., 2005). However, Lengyel's et al. research used data from the National Lightning Detection Network that only detected cloud-to-ground lightning, about 30% of all lightning. Since most lightning is lightning aloft, which still produces thunder, it will usually 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 cited in Lengyel et al. (2005).

Another way to keep informed about the local weather is NOAA 'All Hazards' Radio, formerly NOAA Weather Radio. 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, the repeated weather description and forecast can be used. Only 22.7% of lightning casualties occurred under weather watches or warnings on average from 1994-2004 (Ashley and Gilson, 2009). The key words are lightning, lightning-storm, and thunderstorm (by definition all thunderstorms have lightning).

The lack of lightning alarms reinforces the need for lightning safety public education so individuals can be responsible for their own lightning safety. While NOAA 'All Hazards' radio has some shortfalls on lightning, it is still an excellent way to keep informed about other weather, especially the alarms for severe weather. It also provides information on some 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 thunder.

3.1.2.2 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, conducting paths to the outside should be avoided. Specific examples are in Table-3. In large buildings, inner rooms are generally better.

Table-3.

Examples of conducting paths to avoid when indoors and thunderstorms are in the area.

NO.	SITUATION TO AVOID
1	Do not use corded telephones, except to call emergency services
2	Stay away from electrical appliances, lighting, and electric sockets
3	Stay away from plumbing
4	Don't watch lightning from near windows or doorways

A vehicle with a solid metal roof and solid metal sides also offers good protection; e.g. a typical car, truck, or school bus (Holle, 2008a). The past recommendation has been to avoid contact with conducting paths to the outside to minimize the risk. For example, if parked, lean away from the sides and don't touch the steering wheel, ignition, gear shifter, or radio. Likewise, 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. However, more recent studies indicate that location or posture inside the vehicle makes little if any difference (Holle, 2008a). Vehicles that offer no protection from lightning include motorcycles (Cooper and Holle, 2007), convertibles, bicycles, open framed vehicles, and vehicles with tops made of fiberglass, fabric, or fabric.

A 10-point scale rating locations for lightning safety was developed circa 2000 (Table-4) by two of the authors (Holle and Roeder) and subsequently updated (Roeder, 2008b; 2008c) based on Holle (2008a). While only a subjective estimate of safety, this 10-point scale has proved useful in public education. Over the years, this tool fell into general disuse for unknown reasons. It was recently reintroduced (Roeder, 2010) and is repeated here for use in public education.

3.1.2.3 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 few of these commercial products have been independently and objectively verified. A new report on the performance of these devices is being presented at this conference (DeCaria et al., 2011). 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 lightning but still potentially deadly lightning. There is also much anecdotal evidence of the devices being used improperly. Therefore, the Lightning Safety Group recommended these hand-held detectors not be relied upon, or, at most, be used as a supplement to the other procedures (Holle et al., 1999). While based on now older sensors, the advice still appears to be appropriate (DeCaria, 2011).

Professional grade lightning detectors are available commercially. These devices perform well but may be too expensive for small organizations.

Table 4.
Subjective 10-Point scale for lightning safety provided by various locations. Higher numbers are safer locations.

SCALE	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)

3.1.2.4 Lightning Notification Services

Automatic lightning notification services are a tempting 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 a variety of reliable sources, including the National Lightning Detection Network (NLDN) (Murphy et al., 2009), the U.S. Precision Lightning Network (Neilley and Bent, 2009), or WeatherBug (Heckman, 2011) to automatically notify the subscriber when cloud-to-ground lightning is detected within desired distances of the desired location during the designated time. These services are reasonably inexpensive.

A three-phase approach works well, such as notification when lightning is first detected within 15 miles, as a heads-up that lightning is approaching or developing nearby so plans can be reviewed and staff prepared for action. The next notification is for lightning within a distance that allows enough evacuation time before the lightning

that allows enough evacuation time before the lightning is within 6 miles. This lead-time will vary depending on the location and the number of people who need to be evacuated, but 10 miles is typically used. 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 the subscriber when lightning has not been detected within those distances for the desired time span (typically 30 min), which can serve as an 'all clear' for outdoor activities to resume with reasonable safety.

Notification can be to pagers, cell phones, e-mail, faxes, etc. Some people like these automatic lightning notification subscription services since they provide objective decision points rather than subjective judgments.

However, these notification subscription services have some crucial shortfalls. Some of the systems provide only 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. Of particular concern is when overhead lightning has not reported by a service, since 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. In addition, some of these services have a lag of up 5 minutes or more between the detection of the flash and receipt of the alert. These delays introduce a large risk under some weather conditions. Another shortfall is that some of these automatic notification services use only lightning flashes. Unfortunately, the individual could-to-ground strokes can strike several km away from the flash, i.e. the automated notification system could under-warn the subscriber of the true distance to the closest lightning stroke.

Finally, no detection system will provide protection when the first lightning is a cloud-to-ground flash into the immediate area. An automatic lightning notification service should be used at most to supplement, but not replace, the first levels of the 5-Levels of lightning safety. There is no substitute for planning ahead to avoid the threat and watching the skies for threatening weather and listening for thunder.

Besides the for-fee subscription services, some lightning data are available at no cost at various internet sites. However, these data can lag the lightning by as much as 15 min or more. These time lags are too risky for lightning warnings in many weather situations. These no-fee services also can provide automated notifications when lightning meets the viewer's warnings thresholds.

However, it must be stressed again that there is no substitute for planning ahead to avoid the threat and watching the skies for threatening weather and listening for thunder.

3.1.3 Level-3: Risk Reduction

If a safe place from lightning is not available and people must be outside with thunderstorms in the area, they should at least avoid the locations and activities with the most risk. A typical example would be an outside worker. It is of course much safer not to be outside under this situation. Examples of locations and activities to avoid when outside and thunderstorms are in the area are listed in Table-5. Special emphasis is needed that going under trees to keep dry is dangerous when thunderstorms are in the area.

Again, to reemphasize, this is risk reduction, not safety. By definition, a person is in danger of death or life-long debilitating injury if they get to this level – **NO** place outside is safe, when thunderstorms are in the area!

Table-5.

Examples of locations and activities to avoid when outside and thunderstorms are in the area.

NO.	SITUATION TO AVOID
1	Elevated locations, e.g. mountains or hills, roofs, some playground equipment, etc.
2	Open areas, e.g. sports fields, playgrounds, golf courses, etc.
3	Tall isolated objects, e.g. trees, flagpoles, etc.
4	Water related activities, e.g. swimming, boating, and fishing, etc.
5	Unprotected open buildings, e.g. picnic pavilions, rain shelters, bus stops, dug outs, etc.
6	Open vehicles without solid metal roof and solid metal sides, e.g. grounds keeping equipment (riding lawnmowers, tractors, etc.), open construction vehicles, golf carts (even with roofs), etc.
7	Avoid large or long metal structures like fences and bleachers. A common myth is that metal attracts lightning. However, if lightning strikes a large metal object by happenstance, the electricity can be conducted a long distance, increasing the chance of it causing a casualty.

3.1.4 Level-4: No-notice Personal Backcountry Lightning Risk Reduction

No-notice personal backcountry lightning risk reduction are steps one can take to reduce the risk from lightning if one is outside without a safe location available and lightning threatens. In this context, 'no-notice' means the person was unprepared and no longer has time for a good solution, 'personal' means the only resources the person has are those with him or her, and 'backcountry' means a place safe from lightning is not available. A typical example is a hiker far from a safe location.

The lightning safety community no longer recommends teaching this to the general public. However, this topic may still be appropriate for groups that spend large amounts of time in the outdoors far away from safe locations. This is important since lightning casualties due to outdoor recreational activities far from shelter may be increasing (Holle, 2005b). Details on outdoor risk reduction are discussed in Gookin (2010) and Roeder (2010, 2009a).

3.1.5 Level-5: First Aid

All deaths from lightning are from cardiac arrest. If the person is unresponsive and does not appear to be breathing, CPR should be started. 9-1-1 should be called for professional emergency medical care, preferably by a second person while the first person performs CPR. If available, an Automatic External Defibrillator (AED) can be used. However, CPR should not be delayed to look for one. If the AED detects a treatable rhythm, it will fire; if not, nothing will happen and CPR should be continued until emergency medical technicians arrive and take over. CPR beyond about 20-30 minutes without patient response is usually futile plus rescuers will usually be exhausted mentally and physically by this point and should not feel guilt in discontinuing resuscitation efforts.

3.2 Slogans

Well crafted slogans can make lightning safety easy to remember and interesting to learn. Several slogans for teaching lightning safety are listed in Table-6.

The most popular slogan, 'When Thunder Roars, Go Indoors', has been used in refrigerator magnets by various organizations (Figure-12). The cumulus cloud shape and diagonal lightning bolt help the magnet stand out from the more typical magnet shapes of rectangles, circles, ovals, etc.

A well-crafted slogan often requires considerable effort. It should be short, pithy, rhyme, have a musical meter, and be easy to pronounce. Focus groups can be used to test the slogans. For example, the popular slogan 'When Thunder Roars, Go Indoors!' took about 2-years to find the optimal wording.

Another example is the fundamental principle of lightning safety – '**NO** Place Outdoors Is Safe, When Thunderstorms Are In The Area!'. People's interpretation turned out to be sensitive to the final phrase describing the proximity of the thunderstorm. Some lightning safety educators had used 'in a thunderstorm', but most thought that meant under the thunderstorm, in the rain, or at least the main thunderstorm cloud directly overhead. However, that is far too close to the thunderstorm for lightning safety. Other educators used 'near the thunderstorm', but many people thought that meant being just outside the thunderstorm. After several variations, and many informal focus groups, the phrasing 'in the area' was developed. Most people interpret this to be close enough that you are aware of the thunderstorm cloud, usually up to about 10 miles or more. That is the desired interpretation for lightning safety. As with the 'When Thunder Roars, Go Indoors!' slogan, it took over a year to fine-tune the 'No Place Outdoors' slogan.

3.3 Myth Busting

There are several myths about lightning and lightning safety believed by significant numbers of the public. Myth busting makes lightning safety interesting to learn and has proven to be very effective in lightning safety education. The top-10 lightning safety myths are listed in Table-7. More details on these myths are discussed at Roeder (2007b).

3.4 Enlisting the Media

Enlisting the media is the most efficient method to spread the lightning safety message to the largest number of people. A newspaper article or television broadcast in a major city will often reach more people than an individual is likely to address in an entire lifetime of public speaking. The position statements of the American Meteorological Society and the National Weather Association both call for the media to engage in public education on lightning safety.

TABLE 6.
Lightning Safety Training Slogans

SLOGAN	APPLICATION
NO Place Is Safe, When Thunderstorms Are In The Area!	Fundamental principle of lightning safety
When Thunder Roars, Go Indoors!	When and where to go for lightning safety (Roeder et al., 2003)
Half An Hour Since Thunder Roars, Now It's Safe To Go Outdoors!	When and where to go for lightning safety
Don't Get Fried, Go Inside!	Where to go for lightning safety
Don't Be A Fool, Get Out Of The Pool!	Swimming
Don't Be Lame, End The Game!	Sports
Lightning Kills--Play It Safe!	Increase awareness (NWS, 2001)
Lightning Ignored, Darwin Award!	Increase awareness (McAleenan, 2004)
Use Your Brain, Don't Wait For Rain!	When to go for lightning safety (Lightning Protection Institute)

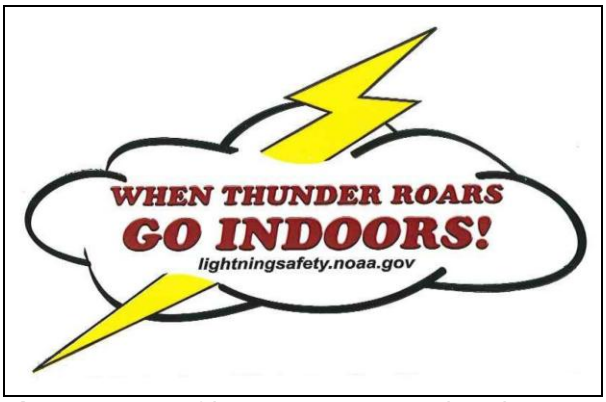


Figure 12. Refrigerator magnet using the most popular lightning safety slogan.

3.5 Teaching Children

As discussed in section-2.1.3, teaching children is one of the most effective methods in lightning safety education. Several tools have been developed to achieve this goal.

'Leon the Lightning Lion' was developed by the Lightning Safety Alliance to teach lightning safety to children. Later 'Leon' was incorporated in an interactive computer game to teach lightning safety to children (Hodanish et al., 2008). A sequence of 17 situations is shown. The player answers if the situations are 'safe' or 'not safe' (Figure-13). Leon provides positive or negative feedback to each answer. In particular, if an 'unsafe' location is chosen as 'safe', Leon is struck by lightning, reinforcing that a potentially life-threatening decision was made (Figure-14). 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 were developed. These posters help teach lightning safety in general, swimming, and outdoor sports (Figure-15 through Figure-17). A coloring page of the general lightning safety poster is also available (Figure-18). Several other lightning safety posters featuring major sports stars and common activities with lightning casualties were also developed. These resources are at the NOAA lightning safety website (www.lightningsafety.noaa.gov).

Children love stickers! To take advantage of that popularity, a sticker based on the popular lightning safety slogan was developed (Figure-19).

3.6 Lightning Survivor Testimonials

The stories of lightning survivors can be heart-wrenching. The long-term injuries present a wide-range of symptoms including chronic pain, fatigue, impaired ability to process information, easy distractibility, short-term memory loss, personality change, and others. Lightning injury can disrupt people's lives, careers, relationships, and aspirations. The public can usually identify with the survivors' poignant stories making them very effective in lightning safety education. Lightning survivors willing to give interviews may be available from the Lightning Strike Electric Shock Survivors, International, a support group for these survivors (www.lightning-strike.org).

TABLE 7.

Pernicious lightning myths and their impact on lightning safety (Roeder, 2007b).

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 10% 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, 2010, 2009a, 2008a, 2008b, 2008c).

TABLE 8.
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		
Medical resource articles	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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Figure 13. A sample question from the Leon the Lightning Lion game.

Figure 14. 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.

4. Resources For Teaching Lightning Safety

Many resources available to teach lightning safety are listed in Table-8. The NOAA lightning safety website is especially useful (www.lightningsafety.noaa.gov). In addition, the authors are available to advise lightning safety education efforts.

Figure 15. Leon the Lightning Lion poster for general lightning safety.

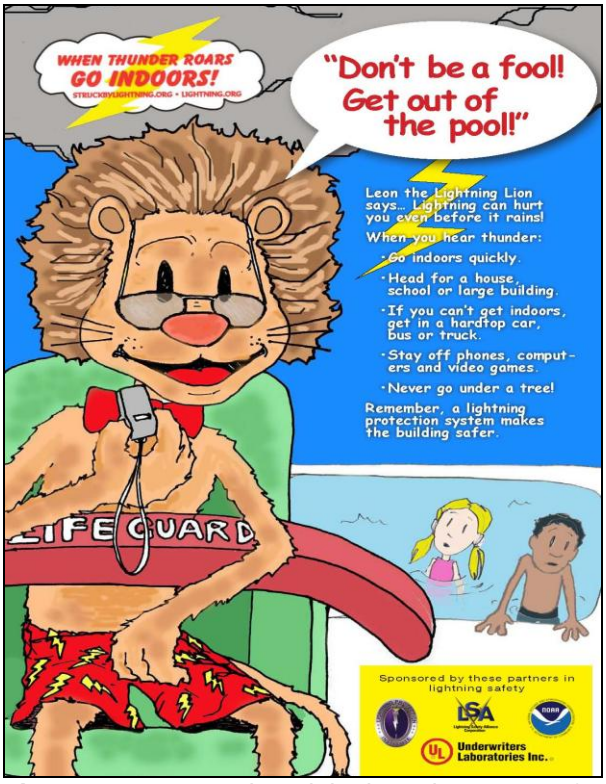

Figure 16. Leon the Lightning Lion poster for swimming lightning safety.

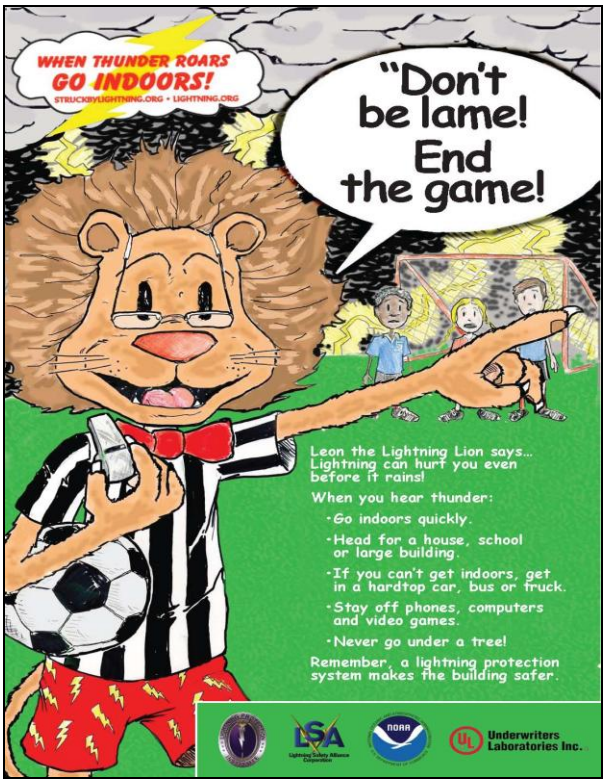

Figure 17. Leon the Lightning Lion poster for outdoor sports lightning safety.

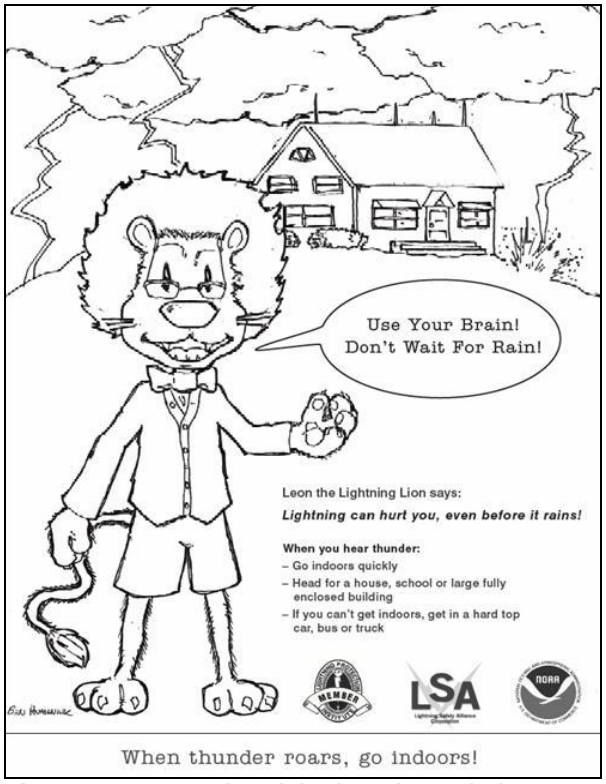

Figure 18. Leon the Lightning Lion coloring page for use in lightning safety education for children.

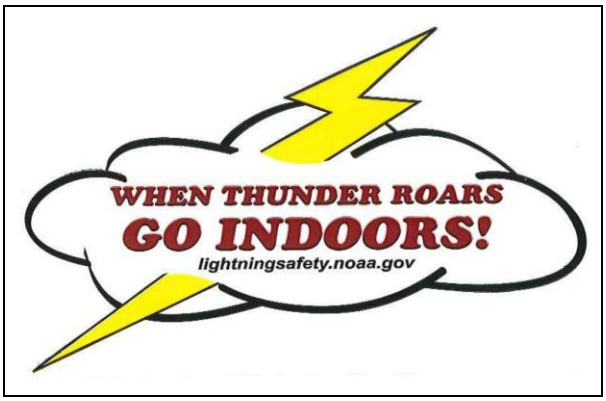

Figure 19. Sticker for children using the most popular lightning safety slogan.

5. Future Work

While significant progress has been made since the Lightning Safety Group met in 1998 (Holle et al., 1999), further improvement in teaching a consensus on lightning safety is still needed. A single standard set of lightning safety guidance can help. The 5-Levels of lightning safety can serve as that standard (section-3.2).

The distribution of lightning fatalities in the U.S. by activity and location in Figure-8 is becoming outdated, especially since a shift in that pattern toward outdoor recreation is occurring (Holle, 2005a, 2005b; Holle et al., 2005). Updating that distribution and figure for a more recent period will help lightning safety education.

The distribution of weather causes of storm and weather deaths, and associated graphics, for each state would help guide how to spend resources in weather safety education. Such a distribution was done for Florida (Figure-4), but also needs updating. Similar distributions by age, such has been done for Florida (Figure-9), can further help guide weather safety education.

Slogans have proven very useful in teaching lightning safety, especially 'When Thunder Roars, Go Indoors!' However, the companion slogan, 'Half An Hour Since Thunder Roars, Now It's Safe to Go Outdoors!' needs improvement. While the content remains correct, it is not as short and pithy as the first slogan and so is not as likely to be remembered, repeated, and used.

The gridded analysis of lightning casualties discussed in section-2.1.1 could be enhanced by normalizing the lighting fatality density by population and/or lightning flash rate. This would isolate the role of behavior in lightning fatalities and indicate areas with above average risky activities. This could then be used to help guide lightning safety education efforts in those areas.

The number of lightning deaths world-wide have been estimated at 24,000 annually (Holle, 2008b) (Holle and Lopez, 2003) making lightning one of the leading sources of weather deaths around the globe. Many of these deaths occur in developing countries. This presents challenges in developing lightning safety guidance for these areas. The U.S. guidelines assume that locations safe from lightning are usually quickly available, i.e. large fully enclosed buildings with wiring and plumbing and vehicles with solid metal roofs and solid metal sides. Unfortunately, these safer locations are often not available in developing countries. In addition, local experts who can apply lightning safety that is culturally relevant are needed. Fortunately, progress is being made (Cooper and Ab Kadir, 2010) (Holle, 2008b) (Holle and Lopez, 2003).

Other research needed to improve lightning safety education is listed in Roeder (2009b) and updated in Roeder (2009c).

6. Summary

Lightning is a significant weather hazard in the U.S. Fortunately lightning safety education is useful in reducing lightning casualties. Lightning safety education is quick, easy, and inexpensive and can be communicated effectively.

Effective communication requires that the public be motivated to learn the information, and that the information taught be effective. Tailoring the message to the audience is the key. Lightning safety education needs to be correct, consistent, credible, easy to use, easy to remember, and interesting to learn. Several tools and techniques for teaching lightning safety were presented and are summarized in Table-9.

The 5-Level method shown in section-3.1 provides a useful organization for lightning safety information and should be used to standardize lightning safety education in the U.S. Slogans are especially effective in teaching lightning safety. In particular, the following three slogans summarize much of lightning safety:

- **NO** Place Outside 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!

Table-9.
Tools and techniques that have proven useful in lightning safety education.

Lightning casualty demographics (state, time, age, location/activity, etc.)
5-Levels of lightning safety
Slogans
Myth busting
Teaching children
Enlisting the media
Lightning survivor testimonials
NOAA lightning safety website (www.lightningsafety.noaa.gov)

7. Acknowledgements

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8. Disclaimer

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

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