JP1.1 RESEARCH REQUIRED TO IMPROVE LIGHTNING SAFETY

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1. INTRODUCTION

Lightning is the second leading cause of storm related deaths in the United States; only floods kill more, as shown in Figure 1 (NOAA, 2006). Lightning kills more than tornadoes or hurricanes in the U.S. using 30 year averages, even after the disastrous hurricane seasons in the early 2000s (Roeder, 2008a). Lightning also inflicts life-long debilitating injury on many more than it kills (Cooper, 1995). Lightning is also a significant weather hazard internationally (Holle and Lopez, 2003). Lightning safety education in the United States has enjoyed an increase in recent years, especially with the NOAA annual Lightning Safety Awareness Week first held in 2001 (Jensenius et al., 2008). While there have been some efforts, lightning safety internationally seems to be lagging. However, research is still needed to improve those lighting safety education efforts. This paper is a subjective list of those research topics based on the author's experience in lightning safety education. This list will necessarily be incomplete. The author hopes this paper will spur discussion that will lead to a more complete list of desired lightning safety research topics.

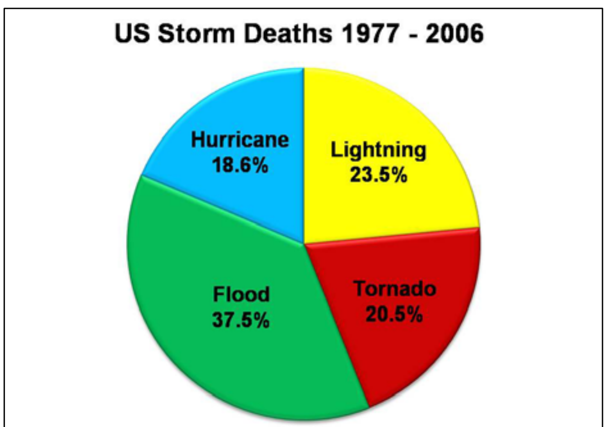

Figure 1. Weather causes of U.S. storm deaths (1977-2006) from NOAA's Storm Data (NOAA, 2007), not corrected for under reporting, which has been significant in past years (Lopez et al., 1993).

2. LIGHTNING SAFETY RESEARCH REQUIREMENTS

Fortunately, most lightning casualties can be easily, quickly, and cheaply prevented. Public education is the key. However, that public education needs to be based on solid scientific evidence and there is still much research that can be done to improve lightning safety guidance. A list of some possible research topics is in Table 1 along with brief notes justifying that research.

3. CURRENT AND DESIRED LIGHTNING SAFETY RESEARCH RESOURCES

NOAA's *Storm Data* (NOAA, 2007) is a well known source of data on lightning casualties. In addition, StruckByLightning.Org, a non-profit organization dedicated to lightning safety education, maintains a several year database of internet media reports on lightning casualties both for the U.S. and internationally. Archives of cloud-to-ground lightning observations by the National Lightning Detection Network are available to researchers. In addition, some locations are accumulating observations of total lightning observations, especially around the Cape Canaveral Air Force Station and Kennedy Space Center from the Lightning Detection And Ranging system since the early 1990s. An on-line collection of important and recent lightning safety papers could be beneficial to new lightning safety researchers. Some on-line listings already exist, e.g. www.uic.edu/labs/lightninginjury/pubs.htm, but need to be better advertised or better updated. A single well maintained website would be best.

4. Summary

Several research topics were listed to improve lightning safety education. This list is anecdotal and necessarily incomplete. It is hoped this list will spur discussion within the lightning and lightning safety community to develop a more complete list of research requirements to improve lightning safety education.

TABLE 1. Research Requirements To Improve Lightning Safety Education (not in priority order)

No.	Research Requirement	Justification
1	Determine distance thunder can be heard versus terrain type, wind, buildings, background noise, being indoors vs. outdoors, and lightning type, etc.	Newest lightning safety guidelines emphasize thunder as cue (Roeder, 2008a, c). Yet studies on the distance that thunder can be heard are very old (Fleagle, 1949) (Veenema, 1920). The lightning and surface observations from Cape Canaveral AFS and Kennedy Space Center would be an excellent data source for part of this project
2	Utility of thunder as a cue in lightning safety	Similar to above, but also lead-time and distance to the first lightning generating audible thunder
3	Continue updating lightning casualty demographics and societal shifts by age, activity, location, etc.	To better target lightning safety education efforts especially given shifts in population and activities
4	Determine frequency and distance distribution of cloud-to-ground lightning outside of <u>rain</u> for various types of thunderstorms	Help overcome the myth that if it's not raining I'm safe from lightning (Roeder, 2007)
5	Determine frequency and distance distribution of cloud-to-ground lightning outside of <u>cloud</u> for various types of thunderstorms	Help overcome the myth that if clouds are not overhead I'm safe from lightning (Roeder, 2007)
6	Anvil Lightning--distance distribution of IC-Ltg and CG-Ltg along, across, and outside anvil cloud. Distribution of lead-time of IC-Ltg vs. CG-Ltg. Frequency of CG-Ltg anvil lighting vs. total CG-Ltg.	Less frequent long distance lightning can violate the normal safety rules (Roeder, 2008a, c). Better understanding of this lightning climatology may lead to better safety rules or at least an understanding of when the lightning safety rules may fail
7	Develop automated lightning warnings that could be implemented by NWS—radar, observed lightning continuity, modeling, etc.	Radar is well known for its ability to forecast the onset of lightning (Roeder and Pinder, 1998) and will likely perform even better when dual polarization becomes available. Observed lightning continuity has been used in commercial products for lightning alerts. Numerical modeling of lightning forecasts has also been researched considerably. If implemented by NWS, automated lightning warnings could vastly improve lightning safety
8	"Bolts From The Blue"—frequency and distance distribution and conditions under which they occur	Infrequent longer distance lightning can violate the normal safety rules (Roeder, 2008a, c). Better understanding of this lightning climatology may lead to better safety rules or at least an understanding of when the lightning safety rules may fail
9	Utility of lightning aloft in lightning safety under different weather conditions, e.g. post squall line stratiform rain	Documenting the gain over just cloud-to-ground lightning will help evaluate the cost-benefit-risk ratios of installing total lightning detectors
10	Continue studies of utility of vehicles in lightning safety	Although using vehicles with solid metal roof and solid metal sides has been part of lightning safety advice for a long time, preliminary research into its effectiveness in the real world has only recently been done (Holle, 2008)
11	Frequency and lead-time distribution provided by lightning aloft and cloud-to-ground lightning when lightning casualties occurred	Some preliminary work has been done (Lengyel et al., 2004) (Holle et al., 1993), but more work is needed, especially for lightning aloft. The distances thunder can be heard will facilitate this topic (No. 1 above)
12	Objectively rate the relative lightning safety provided by houses with/without lightning protection and obeying/not obeying indoor lightning safety rules	Would be used to fine-tune lightning safety guidance. A 10-point scale has proven useful in the past
13	Objectively rate the relative lightning safety provided by different types of vehicles	Would be used to fine-tune lightning safety guidance. A 10-point scale has proven useful in the past
14	Objectively and independently determine performance of commercial hand-held lightning detectors	Many organizations use these devices but their performance remains relatively poorly documented

TABLE 1. ***(Continued)*** Research Requirements To Improve Lightning Safety Education (not in priority order)

15	Objectively and independently determine performance of commercial lightning prediction devices	Many organizations use these devices but their performance remains relatively poorly documented
16	Evaluate lightning safety of indoor pools	Many lightning safety experts believe indoor swimming pools are not safe from lightning, but there are no records of lightning casualties there. Lightning casualties at outdoor pools are well known
17	Develop lightning safety recommendations appropriate for underdeveloped countries	A large portion of lightning casualties are in underdeveloped countries (Holle and Lopez, 2003) where U.S. guidelines do not apply due to the relative lack of appropriate buildings and vehicles
18	Distance from return strokes that ground streamers and step voltages can cause death and injury	Useful in evaluating short notice outdoor lightning risk reduction
19	Distance that lightning can cause casualties when striking conducting objects, e.g. phone wires going inside, plumbing, metal fences, stadium stands, etc.	Useful in lightning safety education
20	Better determine the ratio and severity of lightning injuries versus lightning deaths	One of the main motivators in lightning safety is avoiding injuries
21	Improve relative percentage of lightning casualties due to the five lightning casualty mechanisms	Better support to estimates of the effectiveness of short notice outdoor lightning risk reduction (Cooper et al., 2008) (Roeder, 2009, 2008b, d)
22	Estimate frequency that precursors to imminent lightning occur and are observed by nearby people with sufficient lead-time to take action	Better support to estimates of the effectiveness of short notice outdoor lightning risk reduction (Cooper et al., 2008) (Roeder, 2009, 2008b, d)
23	Refine estimate of the frequency that safe locations were available to lightning victims. This has been estimated as high as 95% (Roeder, 2009, 2008b, d).	Better support the recommendation to not teach last minute outdoor lightning risk reduction to the general public
24	Update lightning casualty underreporting figures	The under-reporting figures come from limited studies and past under-reporting may have changed with increased lighting safety awareness (Richey et al., 2007) (Cherington et al., 1999) (Lopez et al., 1993) (Mogil et al., 1977)
25	Analyze completeness of lightning casualties in NOAA Storm Reports	Self explanatory. One approach is comparison with media reports (Richey et al., 2007)
26	Estimate utility of short-notice outdoor lightning risk reduction for various locations	Risk reduction in a large flat unobstructed area has been estimated (Roeder, 2009, 2008b, d). Other locations such as forests, mountains above and below the timberline, etc. should also be evaluated
27	Professional communicators critique lightning safety slogans	Improve effectiveness and easy memorization of lightning safety slogans. *'When Thunder Roars, Go Indoors!'* is probably good, but *'Half An Hour Since Thunder Roars, Now Okay To Go Outdoors!'* needs improvement
28	Quantify the role, if any, of the composition of an object increasing the probability of lightning striking it. Small metal objects on the body do not attract lightning (zippers, cell phones, i-pods, jewelry, under wire bras, etc.) (Roeder, 2007). Upward leaders appear to be initiated equally easily from conducting and non-conducting objects at the same height and shape near a descending step leader. However, a high impedance object might resist forming an upward leader at larger distances near the edge of a descending step leader's 'looking distance'	This has been an area of discussion between physical scientists and lightning safety educators, and a question sometimes asked by the public
29	Develop semi-portable lightning protection devices for camp sites and very light-weight protection for hikers	Lightning protection light enough to be carried by hikers may not be physically possible

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