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LIGHTNING SAFETY RESEARCH REQUIREMENTS

William P. Roeder
StruckByLightning.Org
West Yarmouth, MA U.S.A.

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.

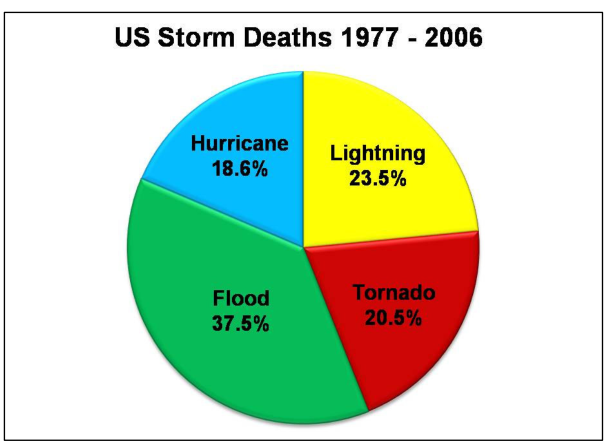

Figure 1. Weather causes of U.S. storm deaths (1977-2006) from NOAA's Storm Data (NOAA, 2007), not corrected for under reporting, which has been significant in past years (Lopez et al., 1993).

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 bases 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, b). 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	Develop lightning safety recommendations appropriate for under developed 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
4	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
5	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).
6	Continue updating lightning casualty demographics by age, activity, location, etc.	To better target lightning safety education efforts especially given shifts in population and activities
7	Better determine the ratio and severity of lightning injuries versus lightning deaths	One of the main motivators in lightning safety is avoiding injuries
8	Improve relative percentage of lightning casualties due to the lightning casualty mechanisms	Better support to estimates of the effectiveness of short notice outdoor lightning risk reduction (Cooper et al., 2008) (Roeder, 2008c, d).
9	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)
10	Determine frequency of cloud-to-ground lightning outside of rain for various types of thunderstorms	Help overcome the myth that if it's not raining I'm safe from lightning (Roeder, 2007)
11	Objectively and independently determine performance of commercial hand-held lightning detectors	Many organizations use these devices but their performance remains relatively poorly documented
12	Objectively and independently determine performance of commercial lightning prediction devices	Performance of these devices remains relatively poorly documented
13	Determine the distribution of cloud-to-ground lightning versus distance across and along anvil clouds	Help reduce lightning casualties from long distance anvil cloud to ground lightning (Demetriades et al., 2004)
14	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)
15	Frequency, distance distribution, and more likely conditions for 'bolts from the blue'	Possible improved safety from these events
16	Objectively rate the lightning safety provided by houses with/without lightning protection, obeying/not obeying indoor lightning safety rules, and different types of vehicles	Would be used to fine-tune lightning safety guidance
17	Develop portable lightning shelters for hikers	May not be physically possible
18	Analyze completeness of lightning casualties in NOAA Storm Report	Self explanatory. One approach is comparison with media reports (Richey et al., 2007)

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