

Using Causes of Weather Deaths in Weather Safety Education and Preparedness

William P. Roeder¹ Kimberly H. Chafin² William A. Ulrich¹ H. Kwun² H. C. Okonkwo²

¹45th Weather Squadron
Patrick AFB, FL

²Lake Nona High School
Orlando, FL

1. OVERVIEW

The distribution of causes of weather deaths should be used to guide weather safety and preparedness education in a region and throughout the year. As an overly simplistic example, people in Colorado don't need rip current education and those in Florida don't need avalanche awareness. Likewise, Buffalo, NY can use heavy snow preparedness reminders in January, while Galveston, TX can use hurricane preparedness in summer. However, it is also important to use the most recent analysis of causes of weather deaths, especially if the relative contributions of the various weather phenomena are changing over time.

This paper presents two updates of causes of weather deaths that are changing over time and should be used to increase the effectiveness of weather safety and preparedness education. The two updates are: 1) weather deaths in Florida, and 2) CONUS tropical cyclone deaths. The poster summarizing this presentation is in Figure-1.

2. BACKGROUND

The updates to Florida weather deaths and CONUS tropical cyclone deaths were done under the Lake Nona High School (LNHS) / 45th Weather Squadron (45 WS) collaborative research program. LNHS is a public high school in Orange County School District located in Orlando, FL. The 45 WS is the U.S. Air Force Unit that provides comprehensive weather services to America's space program at Cape Canaveral Air Force Station (CCAFS) and NASA's Kennedy Space Center (KSC) (Harms et al., 1999). This program began in 2015 and is in its fifth year (as of the 2019-2020 school year). It is summarized in Table-1 and in Chafin et al. (2020).

3. RESEARCH TOPICS

There have been three main projects in the LNHS/45 WS collaborative research program.

- Lightning Launch Commit Criteria climatology
- Update Florida weather deaths
- Update CONUS tropical cyclone deaths

2.1 Lightning Launch Criteria Climatology

The Lightning Launch Commit Criteria are the complex set of weather rules to avoid natural and rocket-triggered lightning strikes to boosting space launch vehicles. This project is not germane to the weather safety/preparedness focus of this paper and will not be discussed. More details on this project are at Chafin et al. (2020).

2.2 Updated Causes of Florida Weather Deaths

The second major project in the LNHS/45 WS collaborative research program updated the causes of weather deaths in Florida. This was needed since the previous analysis of Florida weather deaths was 26 years old (1959-1993) (Figure-3a). In addition, there was strong anecdotal evidence that the rate of lightning deaths in Florida had dropped significantly following over 20 years of intensive lightning safety education. These updated causes of weather deaths are used in the weather safety education efforts by 45 WS for their customers. This update can also be used by all parties doing weather safety education in Florida.

The new causes of weather deaths in Florida are shown in Figure-3b. The percentage of lightning deaths fell by 53% and the per capita lightning deaths fell 81%. This highlights the importance of using the per capita causes of weather deaths, something that is not always done in meteorology. Over the past 30 years, lightning has dropped from the dominant first place causes of weather deaths to a distant second place. The most likely cause is intensive public education on lightning safety that began in the late 1990s.

The trends of weather deaths in Florida were also analyzed. Except for lightning, no causes of weather deaths showed a statistically significant trend over the past 20 years (Table-2). Lightning had a negative trend with a statistically significant non-zero slope ($p = 0.001$) (Figure-4). This is a very encouraging result, strongly indicating that well done weather safety education can be effective. These results are being communicated to weather safety educators throughout Florida.

While the per capita rate of lightning deaths in Florida had a statistically significant trend, the absolute number did not. This again emphasizes the importance of using the per capita rates in weather death analysis.



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William P. Roeder¹ Kimberly H. Chafin² William A. Ulrich¹

HaeJean Kwun² Henry C. Okonkwo²

¹45th Weather Squadron
²Lake Nona High School

Cape Canaveral Air Force Station, FL Orlando, FL



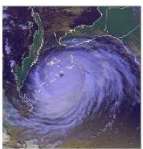
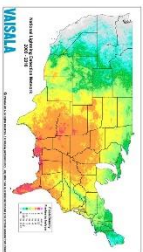
High school students improving U.S. hurricane preparedness!

COLLABORATIVE RESEARCH

- Lake Nona High School, Orlando, FL
 - AP Calculus and AP Statistics classes
- 45th Weather Squadron (45 WS), Cape Canaveral Air Force Station, FL
 - Provides weather support to space program at Cape Canaveral Air Force Station, NASA Kennedy Space Center, and Patrick Air Force Base, FL
- 5th Year in-progress (2019-2020)
 - 4 years completed (2015-2019)
- Lake Nona High School students motivated to pursue Science, Technology, Engineering, and Math (STEM)
- 45 WS gets operational research
- Business Paradigm
 - 45 WS specifies requirements
 - Students decide how to meet requirements
 - In addition to STEM, students also learn:
 - Leadership
 - Management
 - Followership
 - Teamwork
 - Planning
 - Scheduling
 - Speaking & Presentation Skills
- Done on volunteer basis
 - No \$-cost to either organization

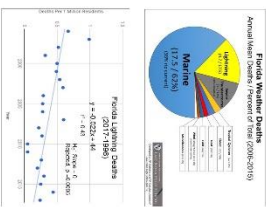
2 MAIN PROJECTS:

- 1) Florida Weather Deaths
- 2) CONUS Tropical Cyclone Deaths



1) Florida Weather Deaths: (Year-4)

- Distribution of weather deaths over past 10 & 30 years
- Lightning deaths since 1998
 - Intensive lightning safety education began in Florida in 1998
 - Annual rate of lightning deaths down 53%
 - Per capita lightning deaths down 81%
 - Only statistically significant trend of all weather deaths
 - **Weather safety education works!**
- Updating results to include 2018



2) CONUS Tropical Cyclone (TC) Deaths: (New!)

- Updated weather causes of CONUS TC Deaths (2006-2018)
- Storm Surge surged from 1% to 49% of deaths
 - Likely due to 2-3 extreme events, especially Hurricane Katrina (2005)
- Storm Surge reverted back to small contributor
- Rain returned as a larger contributor than before
- **Opportunity to improve U.S. hurricane preparedness!**
- On-going Work: Add 2019. Resampling for error bars & hypothesis testing. Analyzing Puerto Rico separately.

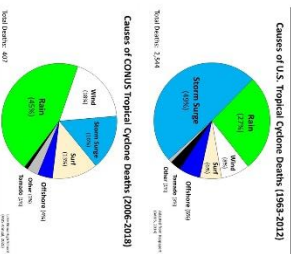
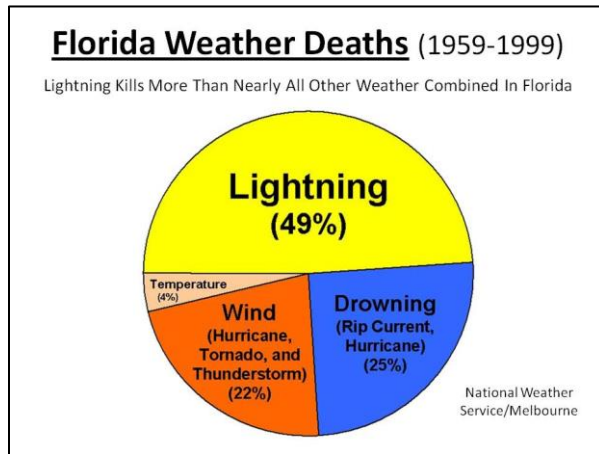


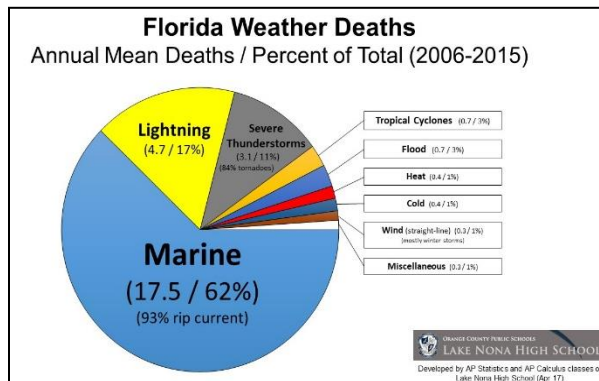
Figure-1. Poster summarizing this paper.

TABLE 1. Projects in the LNHS/45 WS collaborative research program.

| YEAR | TOPICS | NO. STUDENTS | NO. TEACHERS | NO. 45 WS LIAISONS |
|-----------|--|--------------|--------------|--------------------|
| 2015-2016 | • LLCC Climatology | 14 | 2 | 1 |
| 2016-2017 | • LLCC Climatology • FL Weather Deaths | 43 | 2 | 1 |
| 2017-2018 | • LLCC Climatology • FL Weather Deaths • Central Limit Theorem Simulator | 39 | 2 | 1 |
| 2018-2019 | • LLCC Climatology • FL Weather Deaths | 35 | 1 | 1 |
| 2019-2020 | • LLCC Climatology • FL Weather Deaths • CONUS Tropical Cyclone Deaths | 42 | 1 | 2 |



a) Previous causes of Florida weather deaths.



b) Updated causes of Florida weather deaths.

Figure-3. Previous and updated causes of Florida weather deaths. Lightning has fallen from a strong first place to a distant second place over the past 26 years, most likely due to intensive lightning safety education starting in the late 1990s.

Table-2. Hypothesis tests of per capita weather deaths in Florida (1996-2017) for linear slope = 0. Only lightning had a statistically significant trend.

| Weather Phenomena | P-value (H ₀ : slope = 0) |
|----------------------|--------------------------------------|
| Marine | 0.666 (H ₀ not rejected) |
| Lightning | 0.001 (H ₀ rejected) |
| Severe Thunderstorms | 0.462 (H ₀ not rejected) |
| Tropical Cyclone | 0.541 (H ₀ not rejected) |
| Flood | 0.097 (H ₀ not rejected) |
| Heat | 0.867 (H ₀ not rejected) |
| Wind | 0.489 (H ₀ not rejected) |
| Miscellaneous | 0.810 (H ₀ not rejected) |

2.3 Updated Causes of CONUS Tropical Cyclone Deaths

The third major project is updating the causes of tropical cyclone deaths in the CONUS, which just began in 2019-2020. This project was inspired by the previous update of CONUS tropical cyclone deaths (Rappaport 2014) that showed a large increase in deaths from storm surge (Figure-5a).

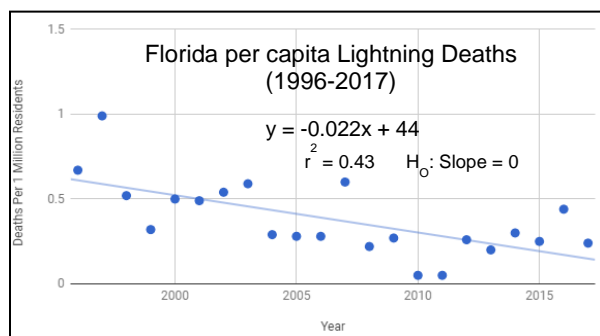


Figure-4. Trend of per capita FL lightning deaths. Lightning is the only weather phenomena with a statistically significant trends in the past 20 years.

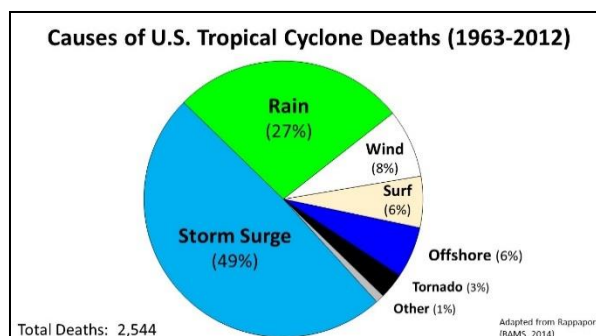
This was different from many previous studies that showed storm surge was a much smaller source of tropical cyclone deaths in the U.S., i.e. typically ~1% and a distant 7th place. Rappaport suggested this may have been due to a few outliers, which one of the authors (Roeder) confirmed in an unpublished analysis. Over 60% of the increase was due to Hurricane Katrina in New Orleans, LA -- one storm in one city significantly skewed the results.

Preliminary results from the ongoing study indicate that the contribution of storm surge to CONUS tropical cyclone deaths has decreased significantly, but not as low as the earlier studies. (Figure-5b). This may be due to the other smaller outliers still being included in this analysis.

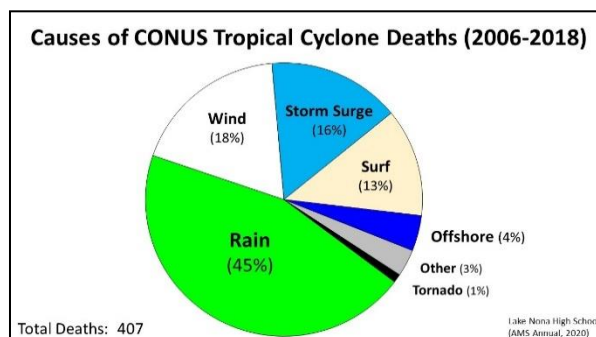
This updated analysis should be considered for use in hurricane preparedness education in the CONUS. While the previous analysis (Rappaport 2014) was valid, it was not as representative of the causes of weather deaths from most tropical cyclones impacting the CONUS. The updated analysis can be useful in hurricane preparedness education for most CONUS events. However, even though not typically representative, the previous result is still useful as a warning of how bad conditions can get if not properly preferred in situations especially susceptible to storm surge.

3. DISCUSSION

The LNHS / 45 WS collaborative research program uses a business paradigm. The 45 WS sets the required deliverables. The LNHS students decide how to meet those requirements, under the guidance of the program teacher. The students come to 45 WS near the end of the school year to present their results. In addition, in 2020 the LNHS students presented their results in two briefings to



a) 1963-2012, adapted from Rappaport (2014)



b) 2006-2018, updated by Lake Nona High School

Figure-5. Causes of CONUS tropical cyclone deaths. The contribution from storm surge decreased significantly and inland flooding from rain returned as the largest contributor.

the annual meeting of the American Meteorological Society (Chafin et al. 2010) (Roeder et al. 2020). The tropical cyclone results are being presented at the 74th Interdepartmental Hurricane Conference in Feb 20. As a result, in addition to learning how to apply statistics to real-world data in the exciting application of space launch, the students also gain valuable skills useful for their future careers. These skills include:

- Leadership
- Management
- Scheduling
- Organization
- Teamwork
- Communication
- Public Speaking.

4. FUTURE WORK

The LLCC climatology will be expanded by adding the most recent 3 years of violations observed by 45 WS during launch countdowns at CCAFS/KSC.

The causes of Florida weather deaths will add resampling to develop error bars for the observed frequencies and allow hypothesis testing if the frequencies differ from each other. In addition, stratifying the Florida weather deaths by geography will be done, if the sample sizes allow. Those stratifications could be coastal vs. inland counties, regions of the state (Florida Keys, Southern FL, Central FL, Northern FL, and the Panhandle), etc. In addition, comparison to the neighboring states may also be done. Finally, more outreach communicating the results to Florida weather safety educators will be done.

The causes of CONUS tropical cyclones is only in its first year and has considerable room for expansion. The data from 2019 will be added. Resampling will be done to develop error bars and hypothesis testing that the current and past frequencies differ with statistical significance. In addition, a sensitivity analysis will be done. Outliers will be identified and removed and the impact assessed. Finally, tropical cyclone deaths in other parts of North America will be added, if justified by the sample sizes: Puerto Rico and other Caribbean islands, Mexico and other countries bordering the Gulf of Mexico, and Central America.

5. SUMMARY

The weather safety/preparedness parts of the Lake Nona High School/45th Weather Squadron collaborative research program were presented. This program is now in Year-5 (as of the 2019-2020 school year). The three main projects in the program have been: 1) Lightning Launch Commit Criteria climatology, 2) update Florida weather deaths, and 3) update CONUS tropical cyclone deaths. The four main points from the weather safety/preparedness parts of the program are:

- Causes of weather deaths should be an important part of weather safety and preparedness education
- Weather safety/preparedness programs can be effective
- Causes of weather deaths should be done on a per capita basis
- The updated causes of CONUS tropical cyclone deaths should be considered to replace the previous analysis (Figure-5b).

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