714 **The Lake Nona High School and 45th Weather Squadron Collaborative Research Program: Year-5**

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## 1. OVERVIEW

Lake Nona High School (LNHS) and the 45th Weather Squadron (45 WS) are in Year-5 of a collaborative research program. LNHS is a public high school in Orange County School District located in Orlando, FL. 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), Patrick Air Force Base, and NASA's Kennedy Space Center (KSC) (Harms et al., 1999). This program is summarized in Figure-1.

This program began in 2015. The year before, 45 WS participated as part of a group to present how we use statistics in the workplace to the Advanced Placement Statistics and Advanced Placement Calculus classes at LNHS. In that briefing, 45 WS mentioned the possibility of doing collaborative research. Although most of the 45 WS research topics were designed for M.S. theses, some of the topics could be descoped and/or extended in duration if needed to allow them to be done by high school students.

## 2. Research Topics

The research topics are selected based on the operational needs of 45 WS that match the skills and interests of the LNHS participants. So far three major and one minor topics have been worked. These topics are summarized in Table-1.

### 2.1 Lightning Launch Commit Criteria Climatology

The Lightning Launch Commit Criteria (LLCC) are the complex weather rules used to avoid natural and triggered lightning to space launches from the United States (NASA 2017) (Krider et al. 2009). A climatology of the LLCC was not possible since they are not routinely observed because a sensor(s) to record the LLCC violated/not-violated condition is not available, the evaluation method is manually intensive, automated evaluation from routinely available weather data is too difficult, as is evaluation from numerical model simulation.

However, a LLCC climatology was highly desired. A frequency distribution of LLCC violations by rule(s), as well as by time of day, day of year, and annually would be very useful. These uses of a LLCC climatology include:

- Concept of Operations design for space launch programs,
- Mission planning for specific space launches within those programs,
- Long range weather forecasts for launches,
- Training Launch Weather Officers, and
- Setting research priorities to increase launch availability and launch safety.

The LNHS students have taken the LLCC conditions observed by 45 WS during launch windows from 2008-2017 to determine which LLCC rules are violated by season and time of day and annually. They also determined the frequency of simultaneous pairs and triplets of LLCC rule violations. Higher order sets of LLCC rule violations were considered but the frequency for quartet violations and higher were too infrequent. One of these results, annual frequency of LLCC violation for each rule is shown in Figure-2. Even though CCAFS/KSC is the busiest spaceport on Earth, the amount of evaluations of LLCC violations was too small relative to the total time to allow a direct climatology. Running best-fit cubic polynomials were used to fill-in the gaps. Finally a spreadsheet was provided that takes the desired day of year and hour of day from the user and provides the expected LLCC violation rate.

This LLCC climatology has been especially useful in guiding LLCC improvements. The Cumulus Rule was found to be the most frequent LLCC violator at CCAFS/KSC. In addition, it is the rule that has gone the longest without an in-depth technical review and thus may have more room for improvement than many of the other rules. This motivated the 'Cumulus Electrification Study' that is now finishing at Florida State University. Initial results indicate that merely optimizing the cloud-top temperatures/ stand-off distance thresholds in the current rule is insufficient. A new Cumulus Rule with different variables is needed, perhaps based on integrated reflectivity between various temperature levels. This is leading to Phase-2 of the Cumulus Electrification Study.

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# Collaborative Research Between Lake Nona High School and the 45th Weather Squadron: Year-5


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## High School Students doing Research for America's Space Program

### COLLABORATIVE RESEARCH

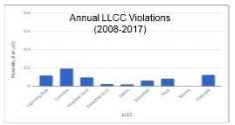
- Lake Nona High School, Orlando, FL
  - AP Calculus and AP Statistics classes
- 45th Weather Squadron (45 WS), Cape Canaveral Air Force Station, FL
  - Provides weather support to space program at Cape Canaveral Air Force Station, NASA Kennedy Space Center, and Patrick Air Force Base, FL
- 5th Year 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

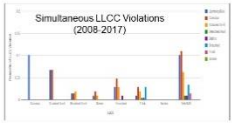
### 3 MAIN PROJECTS:

1) Lightning Launch Commit Criteria (LLCC) Climatology
2) Florida Weather Deaths
3) CONUS Tropical Cyclone Deaths

### 1) Lightning Launch Commit Criteria (LLCC) Climatology: (Year-5)

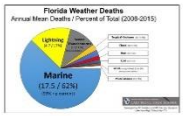
- Complex weather rules to avoid natural & rocket-triggered lightning
- Create LLCC climatology from evaluations during launch windows
- Average LLCC violation rate by seasons, 3-hour blocks
- Frequency of simultaneous LLCC violation pairs
- EXCEL that converts date/time to average LLCC violation
- CONOPS design, Mission planning, LWO training, Research goals
- See briefing 10.2, 20 ARAM (Thu, 0900-0915)

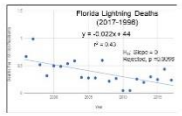



### 2) Florida Weather Deaths: (Year-4)

- Distribution of weather deaths over past 10 & 30 years
- Hypothesis tests for significant trends
- See poster 1390, 15th Societal Apps (Wed, 4 - 6 pm)




### 3) CONUS Tropical Cyclone (TC) Deaths: (New!)

- Updated weather causes of CONUS TC Deaths (2006-2018)
- Key Results: 'Storm Surge' contribution reduced (49% to 16%)
  'Rain' contribution increased (23% to 45%)
- See poster 1390 at 15th Societal Applications (Wed, 4 - 6 pm)

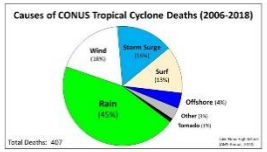



**Figure-1.** Poster summarizing this paper.

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

| ACADEMIC YEAR | TOPICS | NUBER OF STUDENTS | NUMBER OF TEACHERS | NUMBER OF 45 WS LIAISONS |
|---|---|---|---|---|
| 2015-2016 | • LLCC Climatology | 14 | 2 | 1 |
| 2016-2017 | • LLCC Climatology<br>• FL Weather Deaths | 43 | 2 | 1 |
| 2017-2018 | • LLCC Climatology<br>• FL Weather Deaths<br>• Central Limit Theorem Simulator | 39 | 2 | 1 |
| 2018-2019 | • LLCC Climatology<br>• FL Weather Deaths | 35 | 1 | 1 |
| 2019-2020 | • LLCC Climatology<br>• FL Weather Deaths<br>• CONUS Tropical Cyclone Deaths | 42 | 1 | 2 |

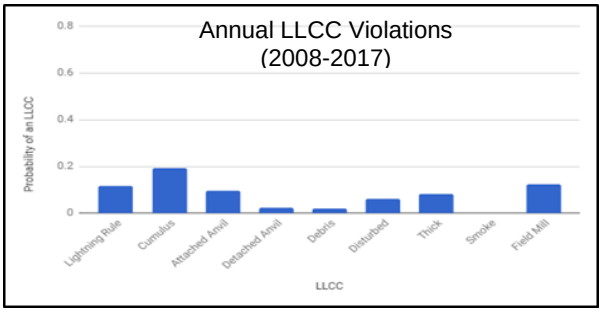



**Figure 2.** Annual violation rate of each LLCC rule.

The LLCC climatology has also been used by the Lightning Advisory Panel to guide LLCC improvement, specifically the frequency of simultaneous violation of the Debris Cloud and Disturbed Weather rule. The Lightning Advisory Panel is the group of atmospheric electricity experts that recommend changes to the LLCC (NASA 2017) (Krider et al. 2009). Finally, the 45 WS has found the LLCC climatology so useful, they are pursuing university level development of an even more sophisticated LLCC climatology with the Air Force Institute of Technology using different data and more advanced statistical techniques.

### 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) and 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. This updated causes of weather deaths is 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 distribution of causes of weather deaths in Florida is shown in Figure-3. 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 cause of weather deaths to a distant second place. The most likely explanation is intensive public education on lightning safety that began in the late 1990s.

The trends of weather deaths in Florida were also analyzed. No causes of weather deaths showed a statistically significant trend over the past 30 years, except for lightning (Table-2). Lightning had a negative trend with a statistically significant non-zero slope ($p = 0.001$). However, the trend for number of lightning deaths (not per capita) did not have a statistically significant trend. This emphasizes the importance of analyzing weather deaths on a per capita basis. More information is at Roeder et al. (2020).

These results are being communicated to weather safety educators throughout Florida.

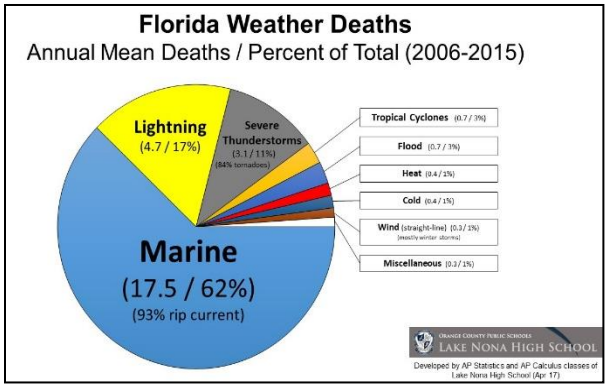


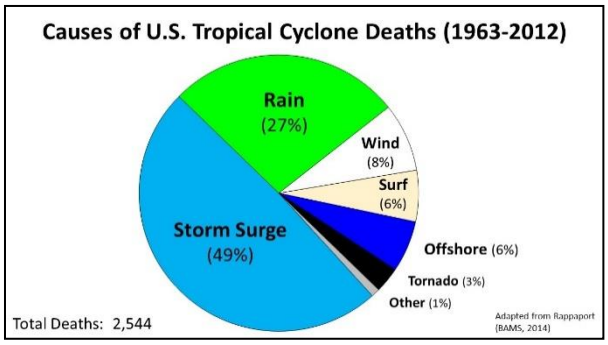

**Figure-3.** Updated causes of weather deaths in Florida.

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

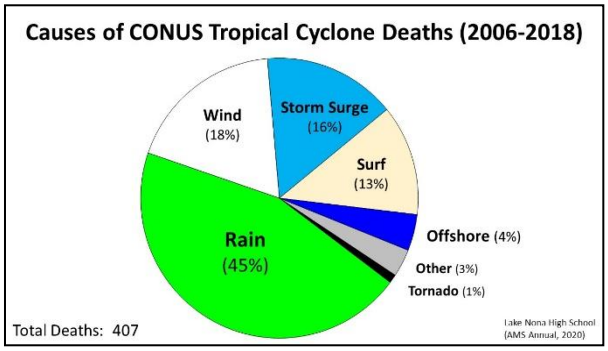
| Weather Phenomena | P-value ($H_o$: slope = 0) |
|---|---|
| Marine | 0.666 ($H_o$ not rejected) |
| Lightning | 0.001 **($H_o$ rejected)** |
| Severe Thunderstorms | 0.462 ($H_o$ not rejected) |
| Tropical Cyclone | 0.541 ($H_o$ not rejected) |
| Flood | 0.097 ($H_o$ not rejected) |
| Heat | 0.867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

### 2.3 Updated Causes of CONUS Tropical Cyclone Deaths

The third major project in this program is updating the causes of tropical cyclone deaths in the CONUS. This is the first year of this project. This project was inspired by the most recent previous update of CONUS tropical cyclone deaths (Rappaport 2014) that showed a large increase in deaths from storm surge (Figure-4a). Rappaport suggested this may have been due to a few outliers, which one of the authors (Roeder) confirmed in an unpublished analysis. Preliminary results from the ongoing study indicate that the contribution of storm surge to CONUS tropical cyclone deaths has decreased significantly, but not back to the previous low levels (Figure-4b). These results will be presented at the 74th Interdepartmental Hurricane Conference (25-26 Feb 20) to make the information available for use in various hurricane preparedness education programs. More information is at Roeder et al. (2020).




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




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

**Figure-4.** Causes of CONUS tropical cyclone deaths. The contribution from storm surge decreased significantly and inland flooding from rain returned as the largest contributor.

### 3. DISCUSSION

The LNHS/45 WS collaborative research program uses a business paradigm. The 45 WS specifies the required deliverables and the LNHS team determines how to provide those requirements, under the guidance of the program teacher. The students visit CCAFS 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 the annual meeting of the American Meteorological Society (Chafin et al. 2020) (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 LLCC students also learn other skills that will be useful in future careers. These skill 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 results of the Lake Nona High School/45th Weather Squadron collaborative research program were presented. This program is now in Year-5 and three main projects have been conducted or are in-progress.

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

## 7. REFERENCES


Chafin, K. H., W. P. Roeder, W. A. Ulrich, M.D. Fraze, H. Kwun, and H. C. Okonkwo, 2020: Collaborative research between Lake Nona High School and the 45th Weather Squadron: Year-5, *29th Conference on Education*, 17-22 Jan 20, 5 pp.

Harms, D. E., A. A. Guiffrida, B. F. Boyd, L. H. Gross, G. D. Strohm, R. M. Lucci, J. W. Weems, E. D. Priselac, K. Lammers, H. C. Herring and F. J. Merceret, 1999: The Many Lives Of A Meteorologist In Support Of Space Launch, *8th Conference On Aviation, Range, And Aerospace Meteorology*, 10-15 Jan 99, 5-9

Krider, E. P, H. J. Christian, J. E. Dye, H. C. Koons, J. Madura, F. Merceret, W. D. Rust, R. L. Walterscheid, and J. C. Willet, 2009, Natural and triggered Lightning Launch Commit Criteria, *12th Conference on Aviation, Range, and Aerospace Meteorology*, Jan 09, 5 pp.

NASA, 2017: NASA standard for Lightning Launch Commit Criteria for space flight, NASA Technical Standard NASA-STD-4010, 27 Jun17, 41 pp.

Rappaport, E. N., 2014: Fatalities in the United States from Atlantic tropical cyclones, *Bulletin of the American Meteorological Society*, 95, Mar 14, 341-346

Roeder, W. P., K. H. Chafin, W. A. Ulrich, H. Kwun, H. C. Okonkwo, 2020: Using causes of weather deaths in weather safety education and preparedness, *15th Conference on Societal Applications of Meteorology*, Jan 20, 5 pp.



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