Analyzing Thunderstorms for Improved Lightning Safety

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INTRODUCTION

Lightning poses a significant safety hazard for all sectors of the nation (public, private, and government). The 'best practices' for lightning safety used in those sectors vary significantly but are all based on passed statistics of lightning in thunderstorms. As the climate changes and thunderstorms generally become more frequent and/or active, these statistics need to be re-evaluated so as to provide the most accurate data. In this study, we develop a lightning clustering algorithm that takes individual lightning strokes and creates thunderstorms based on their spatiotemporal proximity.
We use lightning data from the Earth Networks Total Lightning Network as a basis for these storms. These storm paramters are then compared to various best practice safety rules to determine their validity.
Finally, we split these storms into ocean and land thunderstorms and compare various characteristics (size, duration, flash rate, polarity and IC/CG ratio, etc.) to determine if any differences stand out, which could be useful for aviation safety.

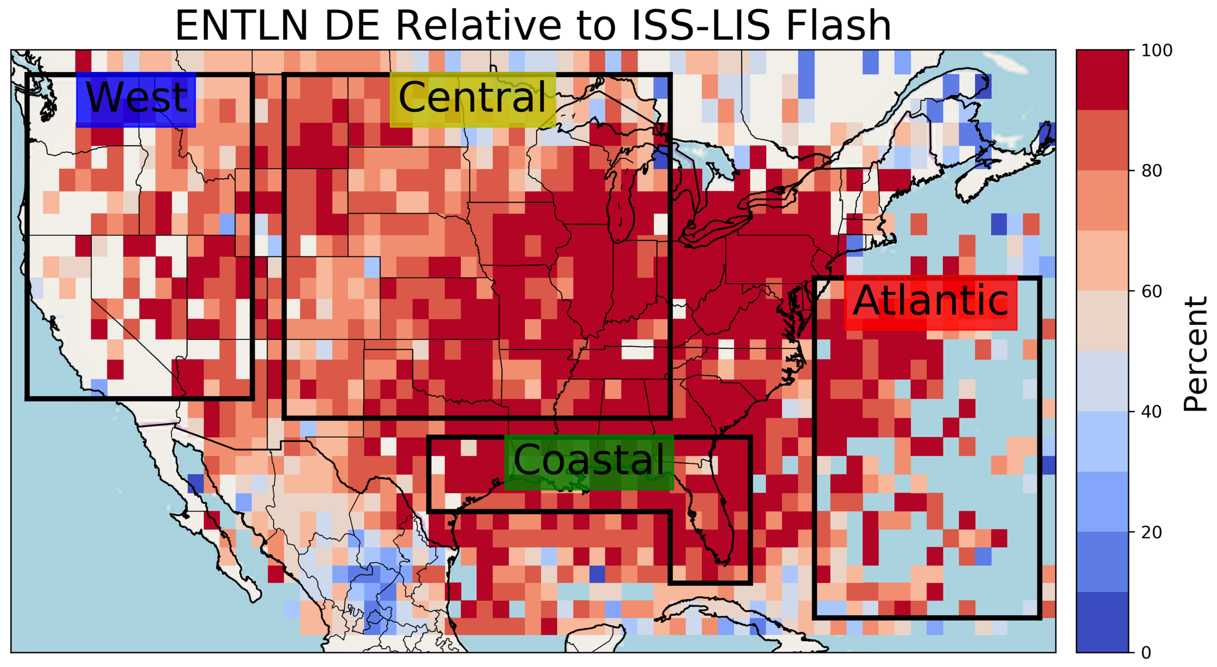
Data

Data used for this study comes from the Earth Networks Total Lightning Network (ENTLN) which consists of over 1800 wideband electric field sensors globally, with about half of those located within the U.S.A.

ENTLN provides time, location, type (Intracloud or Cloud-to-Ground), peak current, and polarity.

We analyzed 125,184,233 pulses between 2019/06/01 - 2019/06/30. This resulted in 22,454 storm clusters.

ENTLN DE Relative to ISS-LIS Flash



Relative to the Lightning Imaging Sensor aboard the International space station (ISS-LIS), ENTLN has a relatively constant detection efficiency throughout all four regions analyzed in this study.

- Four regions are choosen, an oceanic (Atlantic), a coastal, and 2 continental (Central and West) shown in the map above.
- Central storms are generally driven by large frontal systems and should have relatively large and long lasting storms.
- Western and Coastal storms are often driven by more local heating and should be smaller and shorter in duration.

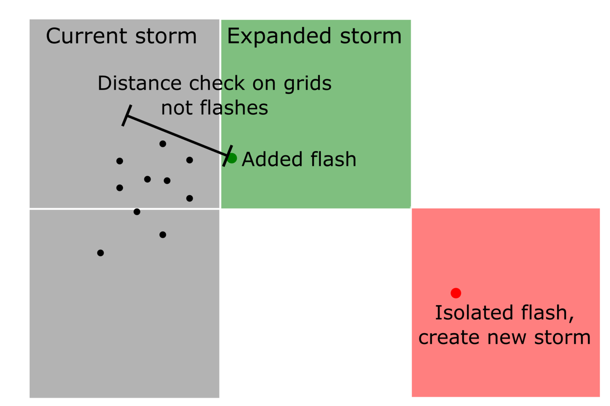
Storm Clustering

A storm in this study is defined as a clustering of lightning pulses that are close in space and time. Storms grow 'organically' and the **pulses are spatially and temporally checked for each grid within the storm, not each pulse**. Checking against grids as oppose to each pulse in the storm significantly reduces computation time.
Each storm tracks all the pulses within it, as well as the start time, duration, and area. The storm area is the convex hull of all the pulses and is calculated using the Shapely python module.

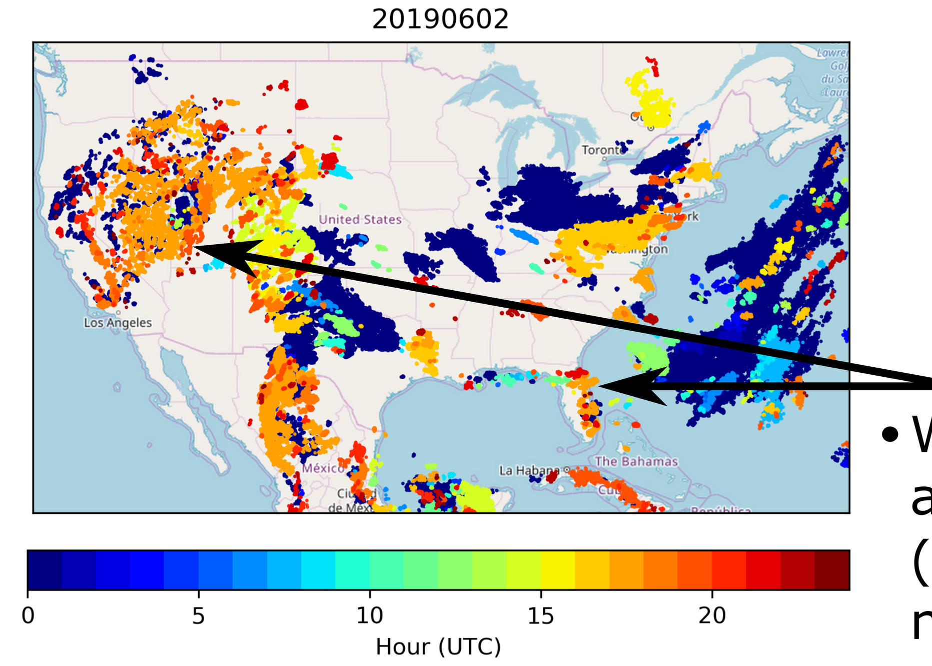
Algorithm logic summary

```
for each flash
  for each storm:
    if time match with entire storm
      if distance match with storm grids
        if matched grids also time match
          add pulse to this storm
  else
    create a new storm
```

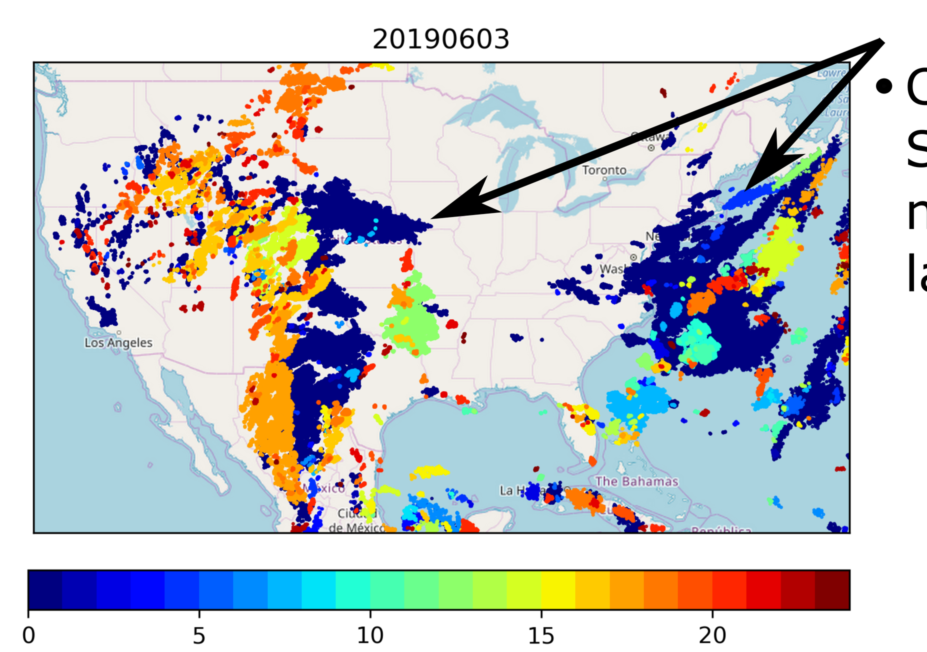
Clustering Parameters
Grid size: 0.2 deg
Distance match: 40 km
Time match: 2 hour



Some daily examples of storm clusters



- West and Coastal storms are more 'popcorn' like (i.e., small and numerous)



- Central and Oceanic Storms appear to be more organized and larger.

Lightning Safety Protocols

30-30 Rule: Once a lighting flash is less than 30 s before the thunder, which is approximately 10 km, go indoors for 30 minutes
When Thunder Roars, Go Indoors: Thunder can be heard about 15 km away
Comparison:
2% of storms have a flash > 30 mins after the last flash of the storm (Max: 119 mins). Mean distance: 39 km
Of those flashes, 0.14% are < 15 km away from the last flash

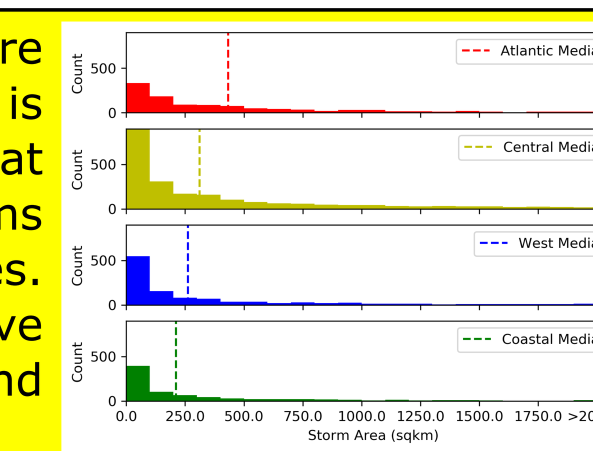
Oceanic vs. Continental

	Atlantic	Central	West	Coastal
Number of Storms	1453	3135	1493	1016
Median Pulses/storm	26	64	43	56
Median Duration (mins)	39	43	57	40
Median Area (sqkm)	432	311	223	210
IC-first %	48	86	87	90
Median IC %	50	91	91	88
Mean +CG %	23	6.9	6.1	3.2
Mean CG (IC) Peak Current (kA)	30 (8.7)	20 (5.2)	21 (4.6)	22 (5.0)

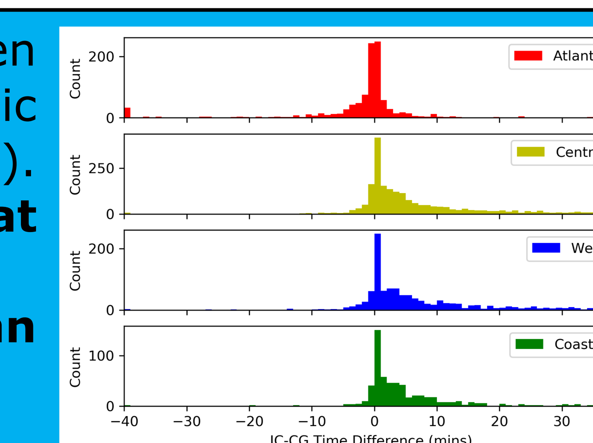
Oceanic storms are significantly less active than continental storms, producing less than half the number of pulses per storm.

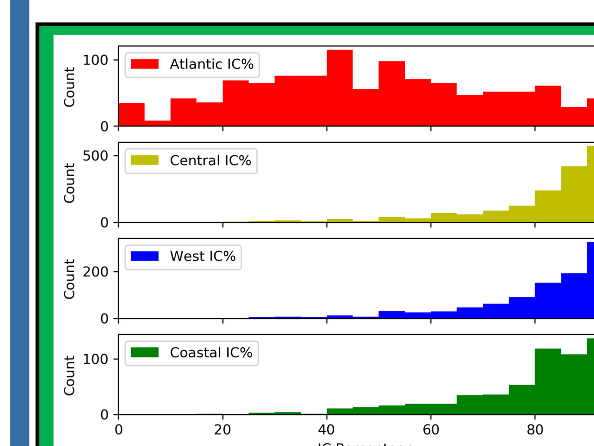
Colored rows are discussed in more detail below

As expected, Atlantic region storms are larger than continental storms, which is statistically significant. Somewhat unexpected is that the continental storms have statistically similar storm sizes. However, the Central region does have more large storms than the West and Coastal region.

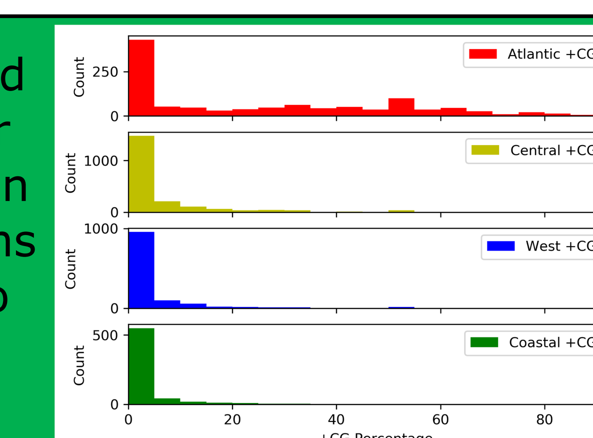


Unlike continental storms, more often than not the first pulse of an oceanic storm is a CG pulse (often by > 20mins). **Limiting to oceanic storms that begin < 100 km of an EN sensor: IC-first = 58% (i.e., this is not an artifact of network performance)**

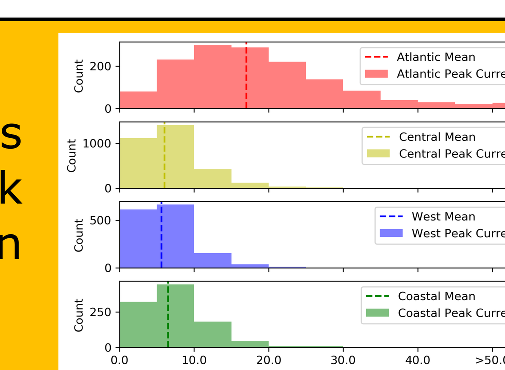




Both IC% and +CG% differ significantly in oceanic storms compared to continental storms.



Oceanic storms produce lightning flashes (both IC and CG) with much larger peak currents, on average 50% larger than continental storms.



Summary

- Lightning safety protocols are still reliable
- Oceanic storms are generally less active, larger, and shorter in duration than continental storms
- More often than not, Oceanic storms begin with a CG pulse, whereas continental storms start with an IC flash >80% of the time
- Oceanic storms have much lower fraction of IC pulses, and higher fraction +CG pulses than continental storms