How Thunderstorms Differ Over Ocean and Land

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Abstract

Many studies have shown that the characteristics of lightning such as size and peak current differ between ocean and continental thunderstorms. In general, the lightning in oceanic thunderstorms are larger and have higher peak current than in continental thunderstorms. The reason for these differences have been stipulated to be related to differences in thermal properties and aerosol concentration, however, there is still disagreement over which is the dominant mechanism. In this study, we focus on how thunderstorm trends, as opposed to lightning trends (i.e., flash density), are affected by these mechanisms. 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 and compare storms from the Eastern U.S.A. to storms off that coast, where the detection efficiency of the network is still good. Once these thunderstorms are obtained, we can split them 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. In this presentation, we will discuss the clustering algorithm used, analyze the results of the study, and discuss implications.

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INTRODUCTION

Many studies have shown that the characteristics of lightning such as size and peak current differ between ocean and continental thunderstorms. In general, the lightning in oceanic thunderstorms are larger and have higher peak current than in continental thunderstorms. The reason for these differences have been stipulated to be related to differences in thermal properties and aerosol concentration, however, there is still disagreement over which is the dominant mechanism. In this study, we focus on how thunderstorm trends, as opposed to lightning trends, are affected by these mechanisms. 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 and compare storms in various regions of the U.S.A. to storms off the Eastern coast, where the detection efficiency of the network is still high. Once these thunderstorms are obtained, we can split them 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.

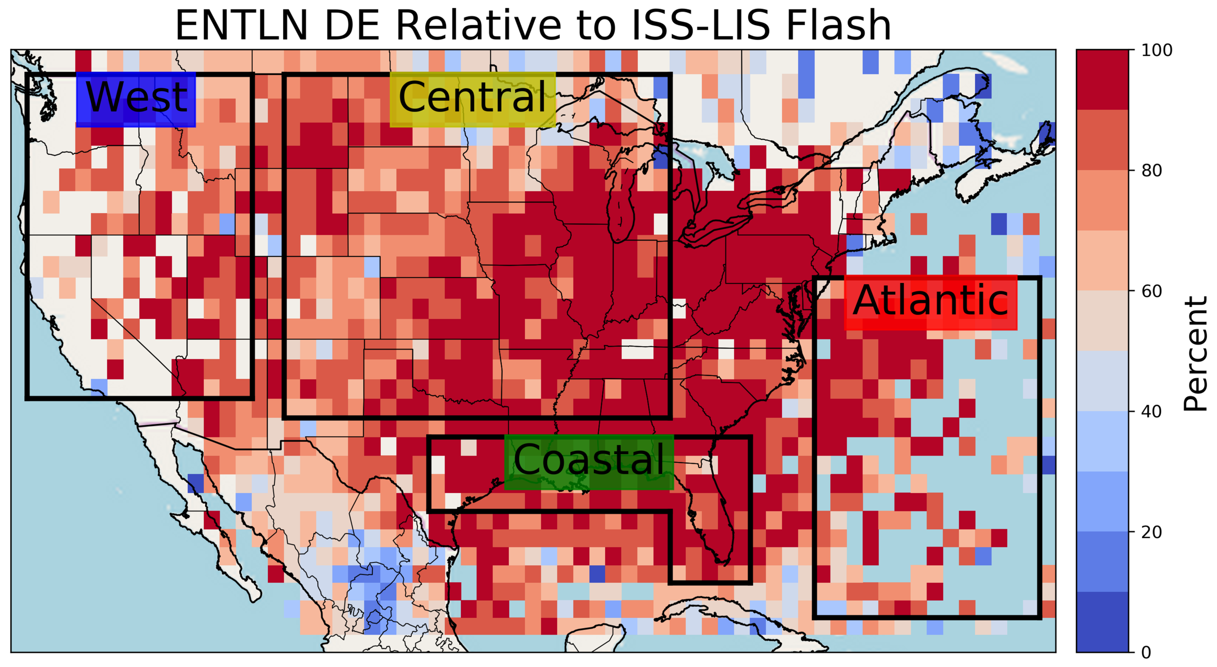
Data

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 83,668,819 pulses between 2019/06/01 - 2019/06/17. This resulted in 17,706 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.

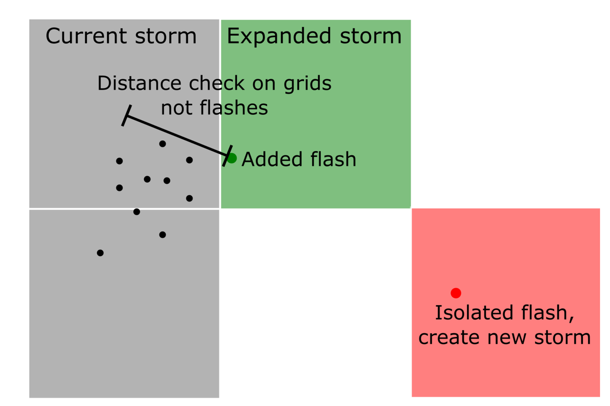
Storm Clustering

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: 1 hour



Some daily examples of storm clusters

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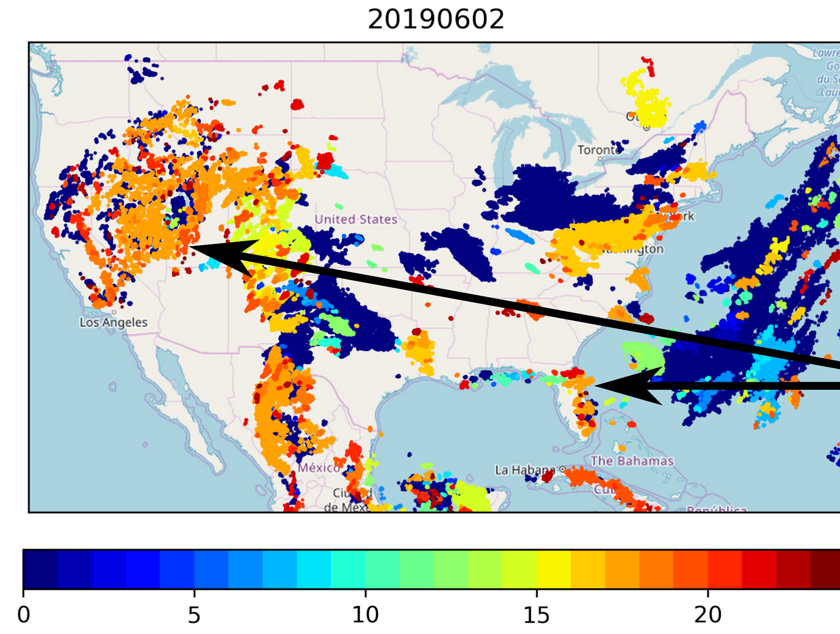

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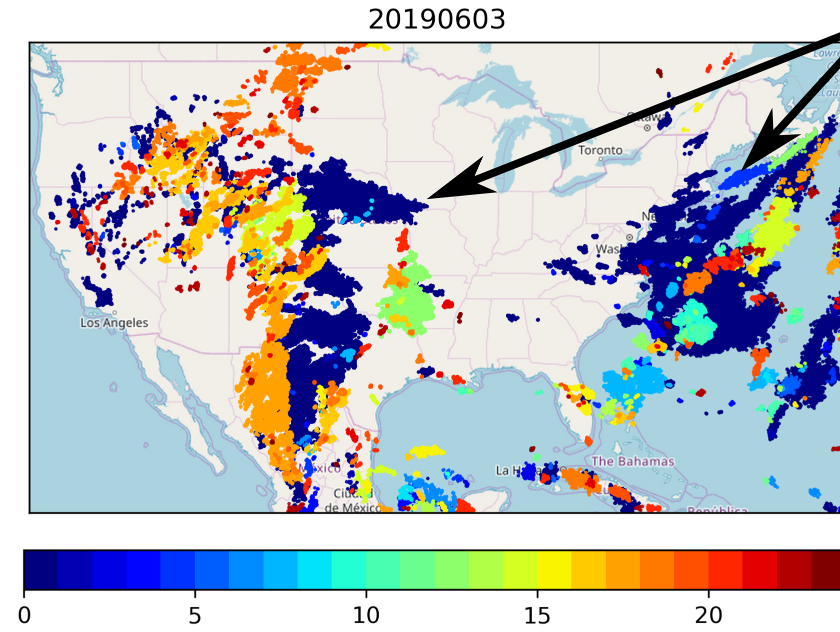

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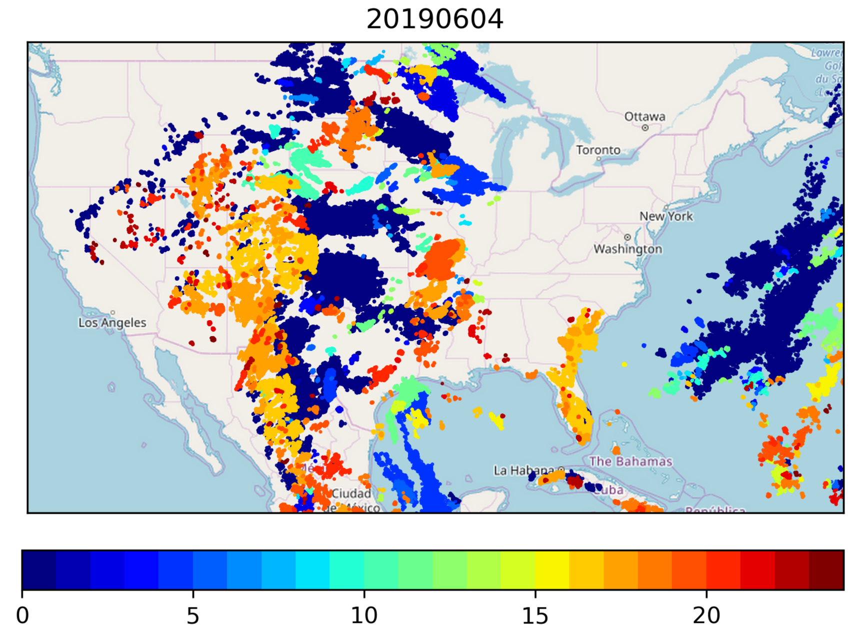


- West and Coastal storms are more 'popcorn' like (i.e., small and numerous)
- Central and Oceanic Storms appear to be more organized and larger.

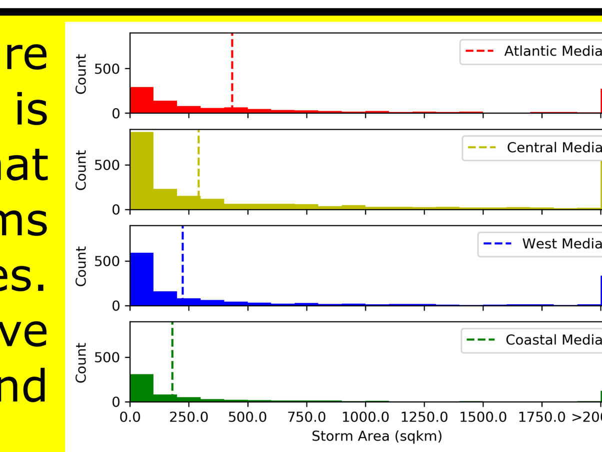
Regional Results

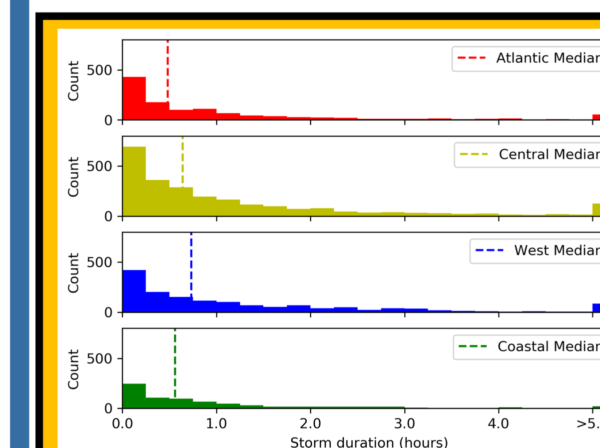
	Atlantic	Central	West	Coastal
Number of Storms	1186	2473	1534	765
Median Pulses/storm	23	63	48	48
Median Area (sqkm)	434	291	223	180
Median Duration (mins)	29	38	44	33
IC-first %	49	87	90	90
Median IC %	50	90	91	88
Mean +CG %	26	7.5	5.5	4

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

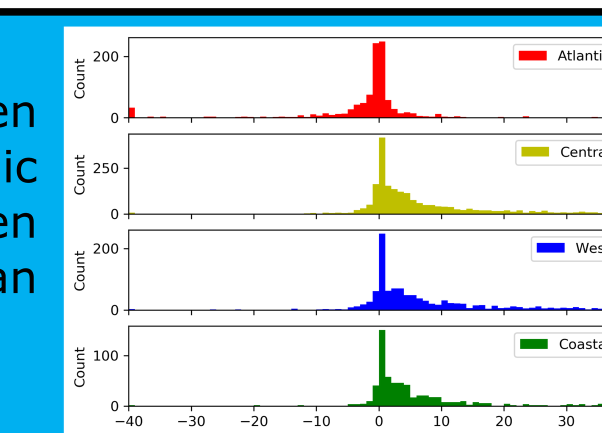
As expected, Atlantic region storms are larger than continental storms, which is statistically significant. Somewhat unexpected is that the continental storms have statistically similar storm sizes. However, the Central region does have more large storms than the West and Coastal region.

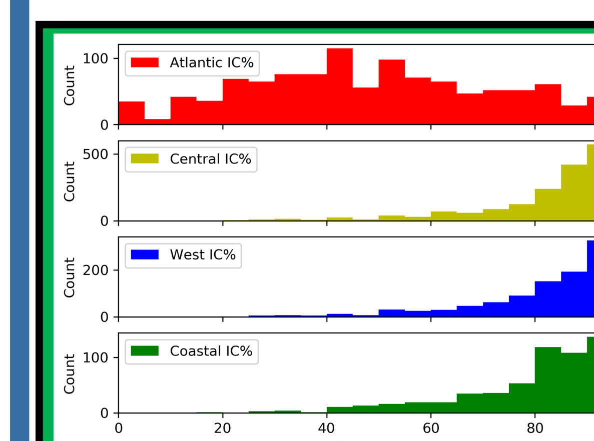




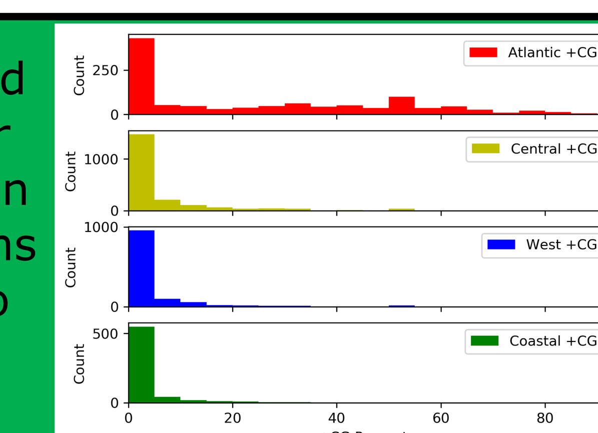
Atlantic region storms have shorter durations than continental storms, which is statistically significant. Surpsingly, storms in the West have the longest duration, which is also statistically significant. However, the Central region does have the lasrgest number of very long lasting (>5 hours) storms.

Unlike continental storms, more often than not the first pulse of an oceanic storm is a CG pulse. This can often preeceed the IC flash by more than 10-20 mins.





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



Summary

- Oceanic storms are generally less active, larger, and shorter in duration than continental storms
- Half of 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