Lightning Clustering to Study Regional Variations in Thunderstorm

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INTRODUCTION

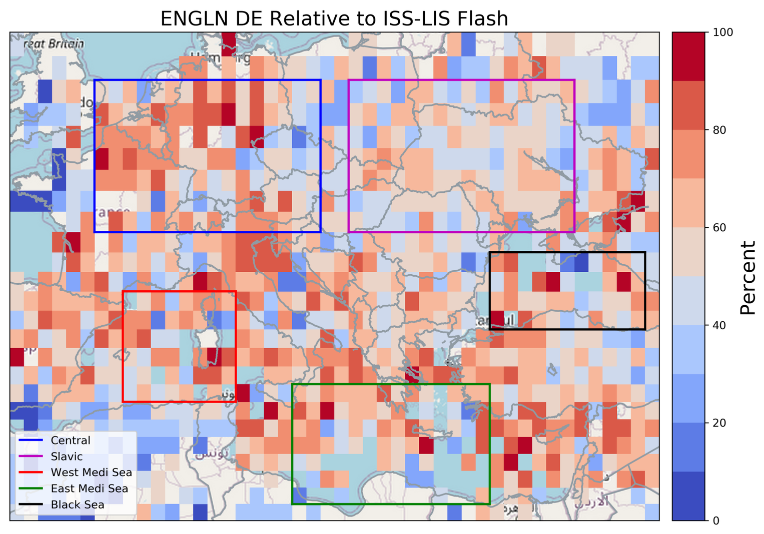
Lightning poses a significant safety hazard for all sectors of the nation (public, private, and government). The 'best practices' for lightning safety used in those sectors vary significantly but are all based on past statistics of lightning in thunderstorms. As the climate changes and thunderstorms 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 parameters are then compared to various best practice safety rules to determine their validity.
Finally, we split these storms into marine and continental thunderstorms and compare various characteristics (size, duration, flash rate, polarity, and IC%).

Data

Data used for this study comes from the Earth Networks GLobal Lightning Network (ENGLN) which consists of over 1850 wideband electric field sensors globally.

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

During the month of June 2019, we analyzed 15,470,532 strokes. This resulted in 12,306 storm clusters.



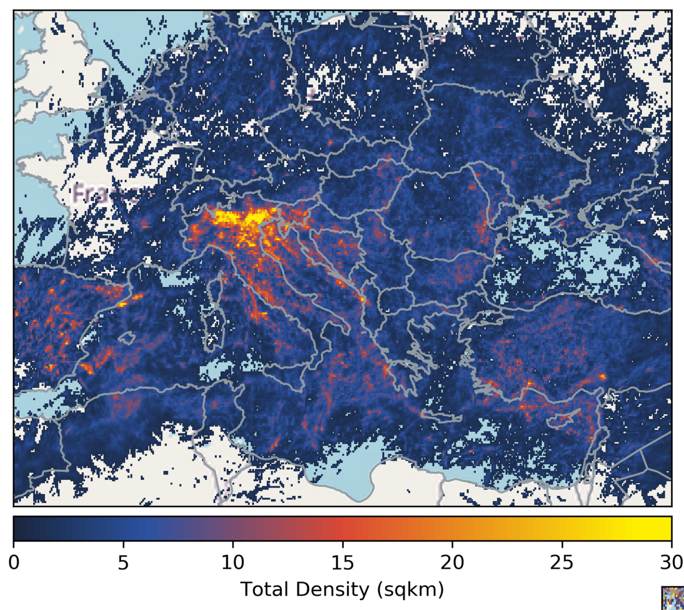
Relative to the Lightning Imaging Sensor aboard the International space station (ISS-LIS), ENGLN has a relatively constant Total (IC+CG) detection efficiency (DE) throughout all five regions analyzed in this study. This DE analysis used data for all of 2019.

The five regions analyzed in this study are chosen according to various lightning parameters shown on the right. Those regions are illustrated in the DE map above and described by their identifying features in the 'Lightning Features' section. The average Total DE (relative to LIS) by region is:

Central:	63%
Slavic:	55%
West Medi Sea:	66%
East Medi Sea:	64%
Black Sea:	65%

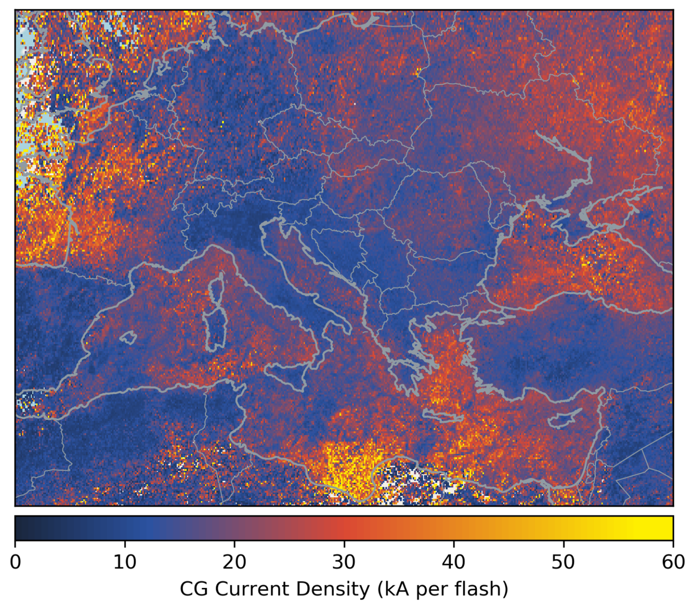
Lightning Features

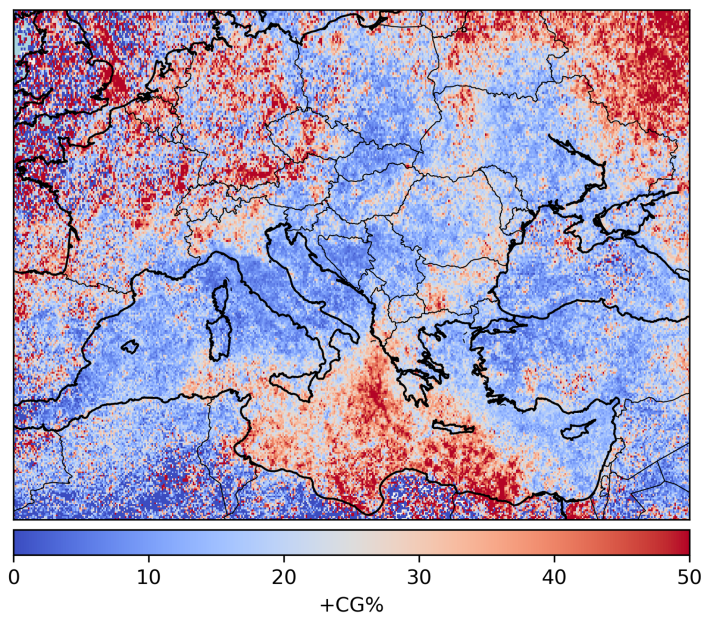
Below are maps of various lightning features. The data used for this analysis was for the entire year of 2019.



Total flash density shows a strong maximum in the Alps and Northern Italy, with a local maximum of 71 flashes per sqkm. Spain also has a relatively large amount of lightning, as do Slovenia, Croatia, and Bosnia and Herzegovina. Turkey experiences high lightning frequency, especially in the South.

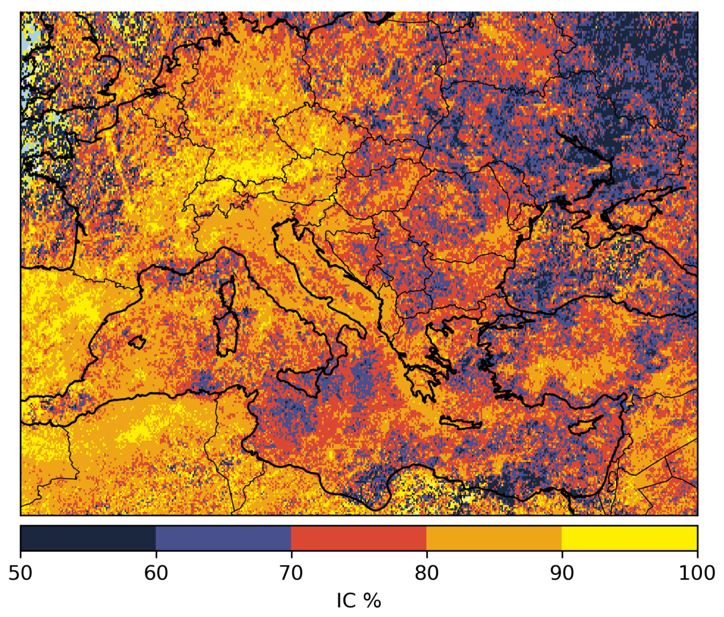
To the right is a map of the average peak current density per CG flash. There are clear and sharp differences over marine areas (such as the Meditereanean and Black Sea). Western and Northern France experiences high average peak currents (as well as large +CG% seen in the map below).





Region	Features
• **Central:**	Continental High +CG High IC%
• **Slavic:**	Continental Low +CG% Low IC%
• **West Medi Sea:**	Marine Low +CG% High IC%
• **East Medi Sea:**	Marine High +CG% Low IC%
• **Black Sea:**	Marine Low +CG% Low IC%

Note: Storms must be completely within a region during its entire lifetime to be included.



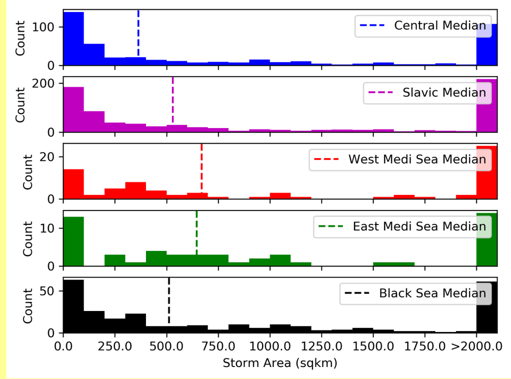
Marine vs. Continental

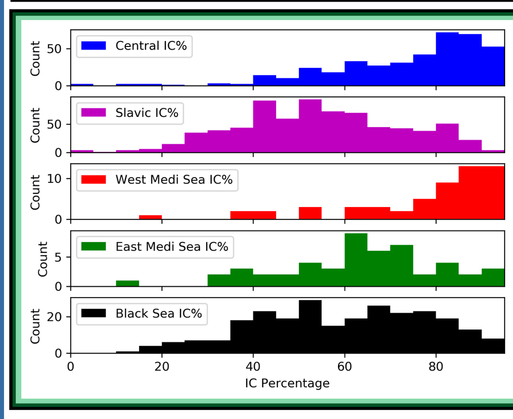
	Central	Slavic	West Medi Sea	East Medi Sea	Black Sea
Number of Storms	453	750	75	53	277
Median Strokes/storm	30	33	17	41	32
Median Duration (mins)	50	52	65	53	54
Median Area (sqkm)	363	530	670	646	511
Median IC %	80	53	88	66	61
Mean +CG %	14	11	11	10	10
Mean CG (IC) Peak Current (kA)	22 (7.0)	23 (10)	19 (5.9)	19 (7.9)	28 (9.2)

The West Medi Sea region has significantly less activity than the rest of the regions, producing about half the number of strokes per storm, but also the largest and longest duration storms. The most electrically active thunderstorms are surprisingly in the East Medi Sea (marine) region. The Eastern regions (Slavic, East Medi Sea, and Black Sea) all have the lowest IC%. The Central region has the highest +CG%, however, not much higher than typically found in thunderstorms (~10%).

Colored rows in the table are discussed in more detail below

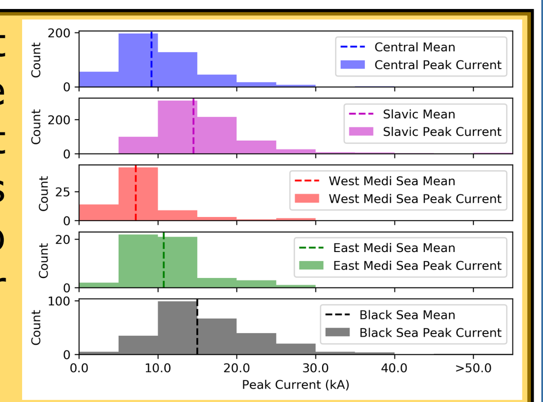
The Central region storms are the smallest of the five regions, which is statistically significant. Both Meditereanean Sea regions experience the largest storms, while the Black sea and Slavic regions are somewhat smaller. The size of the region does not seem to be a factor, since the Black Sea region is the smallest area, but does not have the smallest storms.



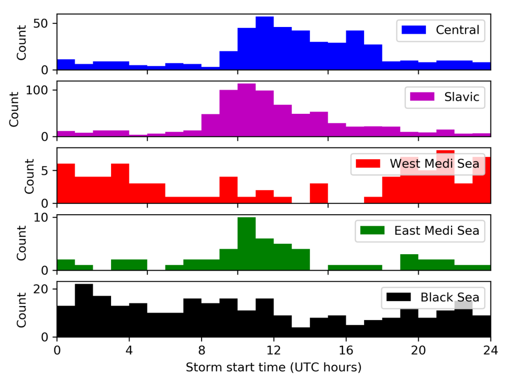


The IC% distributions for the Central and West Medi Sea regions are much more high-sided, whereas the Slavic, East Medi Sea, and Black Sea regions have much more varying distributions.

The Black Sea region has the largest average CG peak current, which may be related to the high salinity. Next highest is the Slavic region. While this region has the lowest DE, it should not be enough to account for the difference between, for example, the Central region.



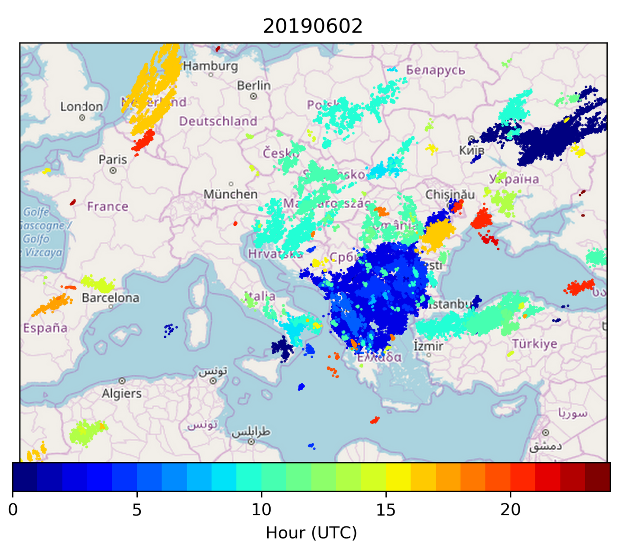
Most storms in the continental regions start in the afternoon, which is to be expected. The East Medi Sea is similar to the continental regions, with start times also in the afternoon. For the West Medi Sea, the start times tend to be in the during the night, while the Black Sea storms don't seem to have a prefereantial start time.



Storm Clustering

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

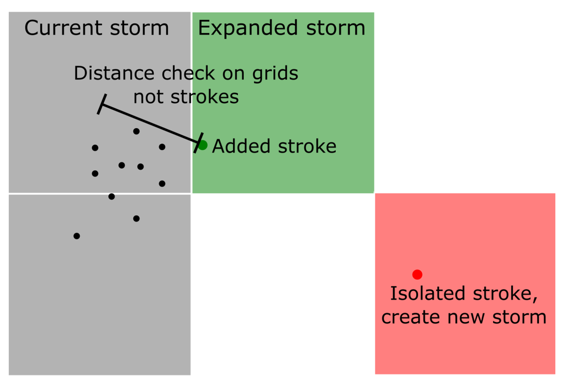
Example day of 'storms', colored by start time.



Algorithm logic summary

```
for each stroke
  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



Lightning Safety Protocols

30-30 Rule: Once a lighting stroke 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:
2.3% of storms have a stroke > 30 mins after the last stroke of the storm (Max: 118 mins). Mean distance: 31 km
Of those strokes, **0.17% are < 15 km** away from the previous stroke

Summary

- Colloquial lightning safety protocols are still reliable
- Storm-based analyses produce very different results than flash-based analyses. This may occur because, in this storm-based analysis, only 'local' storms which completely exist within the region during its entire lifetime are inlcuded (i.e. storms that enter/exit the region do not get included).
- Contrary to past results from similar analyses that found that continental storms produce much more active storms, the East Medi region, a marine region, consists of the most electrically active thunderstorms.
- The Black Sea region experiences the highest average CG peak current, possibly hinting at an elevated surface salinity effect.
- The start times of the continental and East Medi Sea region storms preferentially starting in the afternoon, while the West Medi and Black Sea regions are much more variable.