Comparing lightning Superbolts detected independently in the optical and VLF ranges

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Introduction

Superbolts are exceptionally intense lightning flashes, first identified over four decades ago. Despite significant research, no universal definition has been established due to inconsistencies in detection methods and datasets. This study aims to investigate Superbolts' characteristics and explore the feasibility of defining them consistently across multiple lightning monitoring systems.

Superbolts Definition Summary

Source	Monitoring System	Peak Power Threshold (W)	Energy Threshold (J)	% of All flashes
Turman (1977)	VELA	$10^{11} - 10^{13}$	$> 10^{9}$	0.21%
Kirkland (1999)	FORTE (PDD)	$> 10^{11}$	-	0.4%
Holzworth et al. (2019)	WWLLN	-	$> 10^{6}$	0.0004%
Peterson & Kirkland (2021)	FORTE (PDD)	$> 10^{11}$	$> 10^{8}$	0.21%
		$> 3.5 * 10^{11}$		0.01%

Research Questions

- What defines a Superbolt, and are current definitions consistent across datasets?
- How do Superbolt characteristics vary by monitoring systems and regions?
- Is it possible to establish a universal, method-agnostic definition for Superbolts?

Methodology

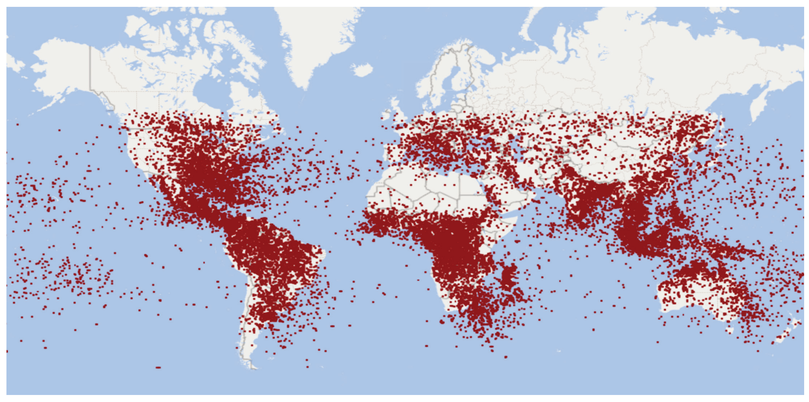
- Data: ISS Lightning Imaging Sensor (LIS) ,World-Wide Lightning Location Network (WWLLN), Earth Networks Total Lightning Network (ENTLN)
- Applied statistical thresholds to define optical Superbolts (top 0.4% and 0.04% brightest flashes).
- Correlation analysis between LIS and ENTLN data using temporal and spatial matching criteria
- Comparative analysis of global Superbolt distributions and temporal trends across systems.

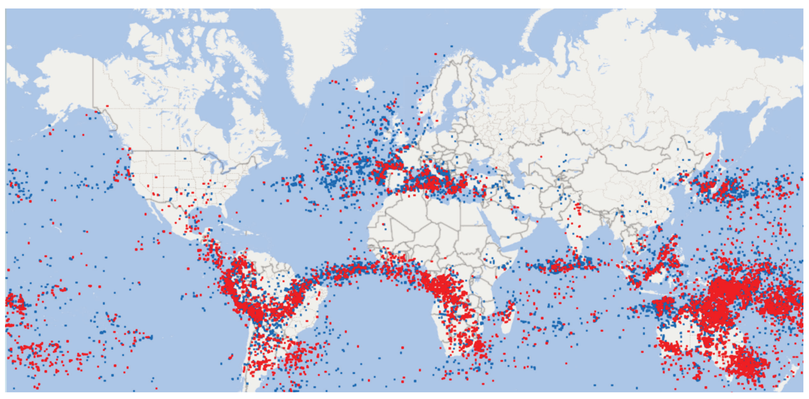
Results

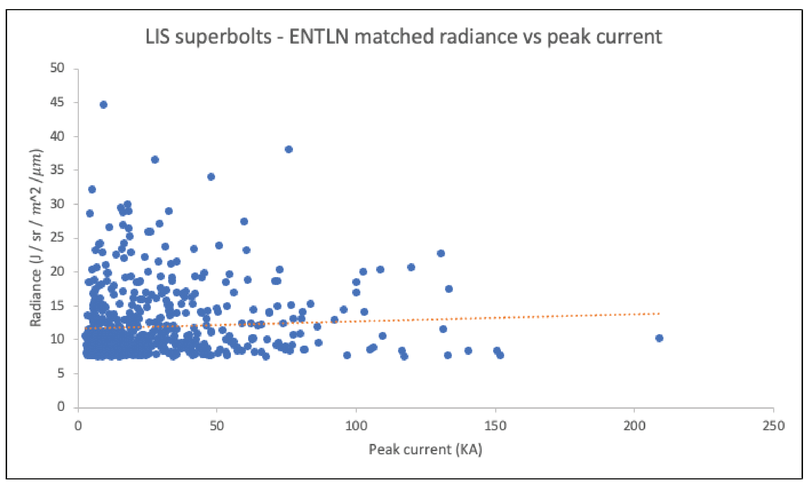
Global Distribution: High-density Superbolt regions identified in South America, South Africa, and the Maritime Continent. Variations observed across systems, with LIS showing summer peaks and WWLLN showing winter dominance.

Correlation Analysis: insignificant correlation found between LIS radiance and ENTLN peak current, highlighting the challenges of comparing datasets from optical and RF-based systems.

Definition Challenges: Results suggest that differences in detection technologies and methodologies might the establishment of a universal definition.







Future Work

- Incorporate meteorological data, such as cloud cover and storm structure, to refine inter-system analyses.
- Investigate global lightning activity patterns to identify potential drivers of Superbolt distribution.
- Develop system-specific or statistical definitions to improve consistency and applicability across datasets.

References

Turman, B. N. (1977). Detection of lightning superbolts. Journal of Geophysical Research (1896-1977), 82(18), 2566–2568. https://doi.org/10.1029/JC082i018p02566

Holzworth, R. H., McCarthy, M. P., Brundell, J. B., Jacobson, A. R., & Rodger, C. J. (2019). Global Distribution of Superbolts. Journal of Geophysical Research: Atmospheres, 124(17–18), 9996–10005. https://doi.org/10.1029/2019JD030975