Overview of Lightning During the Lake-Effect Electrification (LEE) Field Campaign

Benjamin Lamsma, Thomas Weist, Dr. Scott Steiger, Dr. Yonggang Wang
Department of Atmospheric and Geological Sciences, SUNY Oswego

Introduction

- The Lake-Effect Electrification (LEE) project aims to study lightning from lake-effect systems, as well as tower-initiated lightning, to better understand these processes.
- Data collection for Project LEE took place on the eastern side of Lake Ontario near the Tug Hill Plateau.
  - One of the instruments used to collect lightning data was the Lightning Mapping Array (LMA), in which a network of 16 stations was placed across the Tug Hill region.
- The field campaign lasted from 13 Nov 2022 to 3 Feb 2023, in which there were 11 intensive observation periods (IOP) studying lake-effect events, along with lightning detected in between IOPs and an extratropical (ET) cyclone. 239 flashes were recorded in total.
  - The time period for each IOP is determined when the Doppler on Wheels (DOW) mobile radar was in operation during the event.

Methodology & Results

- LMA stations detect radiation sources, points along a flash in time and space, and store them for future use.
  - 4-D plots are the most common use.
- The parameters χ^2 of 1 (goodness of fit for solutions) and min. events per flash of 5 were used to process the data for each IOP.
  - Different LMA station minima (number of stations that detect a source) were used to determine the best value for detecting flashes.
- LMA plots (Fig. 1) consist of 5 sections; elevation vs time, long, lat, and frequency and lat vs long. The later section includes county lines and coastlines, markers for tall objects, along with the flash source data.
- When manually identifying a source as part of a singular flash, the criteria of 0.15s and 3km between consecutive sources were used (Bruning and Macgorman 2013).
- Fig. 1 shows the LMA plot of the flash that struck the Oswego, NY power stack; Figure 2 is a photo (from Kaitlyn Jesmonth) of the lightning striking the stack.
  - The closest source of the flash that struck the Oswego stack had an elevation of 2.000km MSL, and occurred 0.150km away, while the height of the tower is only 0.305km MSL.
  - The flash occurred about 70km away from the center of the LMA network, which likely contributed to the ht. error.
- Fig. 3 shows the difference in sources detected between using a station minimum of 5, 6, and 7 to detect a source for an individual flash during IOP3.
  - Station min. of 5 had more noise compared to the other station min. values; a station min. of 7 had less detail and missed some smaller flashes.

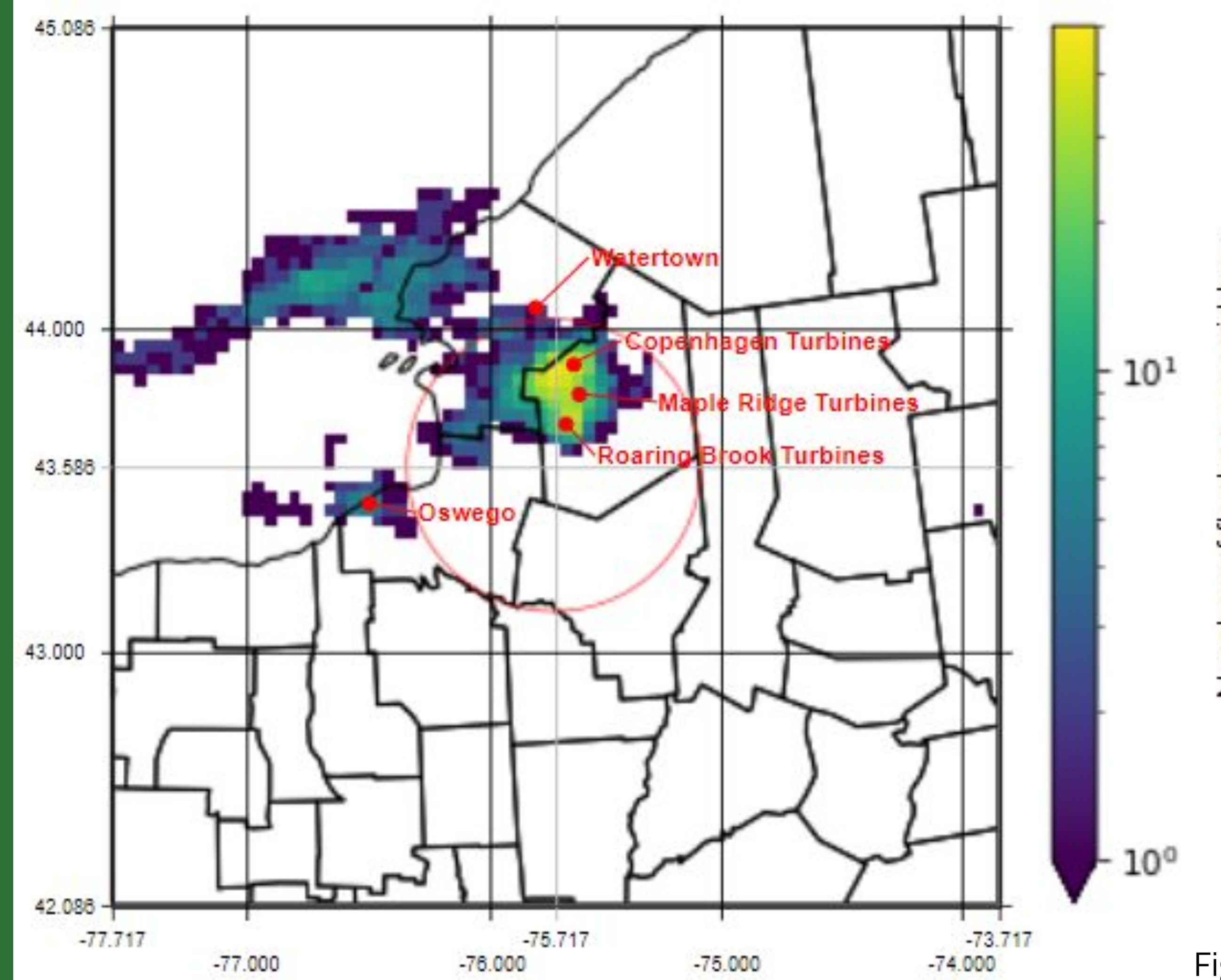

Figure 5: Lightning density map from November 2022 to February 2023. The highest concentration of lightning occurred over the Tug Hill (Roaring Brook, Maple Ridge, and Copenhagen wind turbine farms), along with a significant concentration over northeastern Lake Ontario in Canada.

Fig. 5

Table 1: Start time, end time, number of flashes, and flashes within 0.100 km of a tower of each IOP and other lightning events. The events colored in dark green all have flashes that occurred within the 0.100km tower interaction distance.

	Start Time (MM/DD/YYYY; UTC)	End Time (MM/DD/YYYY; UTC)	Total Number of LMA Flashes	Number of Flashes within the Tower Interaction Distance*
IOP 1	11/13/2022 0930	11/13/2022 1700	0	0
IOP 2a	11/17/2022 0800	11/17/2022 1600	11	0
Misc 1	11/18/2022 0800	11/18/2022 1600	26	1
IOP 2	11/18/2022 1830	11/19/2022 0630	9	1
Misc 2	11/19/2022 0630	11/20/2022 1000	32	11
IOP 3	11/20/2022 1000	11/20/2022 2300	58	7
Misc 3	12/1/2022 0200	12/1/2022 0800	43	2
IOP 4	12/17/2022 2300	12/18/2022 1530	0	0
Misc 4	12/18/2022 1530	12/19/2022 1000	21	1
IOP 5	12/19/2022 1000	12/19/2022 1800	0	0
Misc 5	12/23/2022 1600	12/23/2022 1800	4	0
IOP 6	01/24/2023 1530	01/24/2023 2200	0	0
ET Cyclone	01/25/2023 1900	01/26/2023 0000	28	0
IOP 7	01/27/2023 0500	01/27/2023 0730	0	0
Misc 6	01/28/2023 1200	01/28/2023 1430	2	0
IOP 8	01/28/2023 1430	01/28/2023 1730	0	0
IOP 9	01/31/2023 0500	01/31/2023 1030	0	0
IOP 10	02/01/2023 1030	02/02/2023 0030	0	0
IOP 11	02/02/2023 2200	02/03/2023 0330	5	0
Note	* flash occurred <0.100 km from a tower			

Tbl. 1

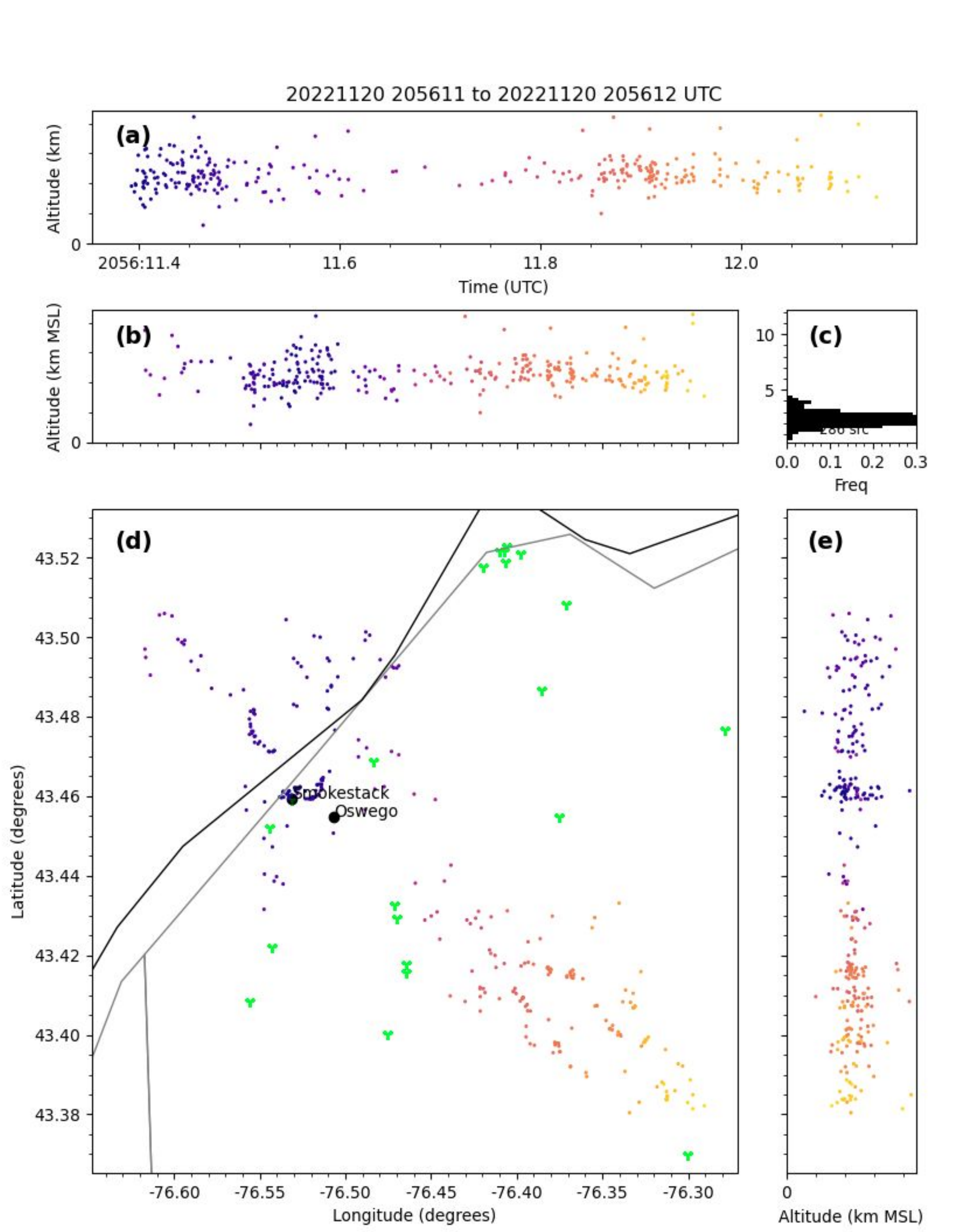

Fig. 1

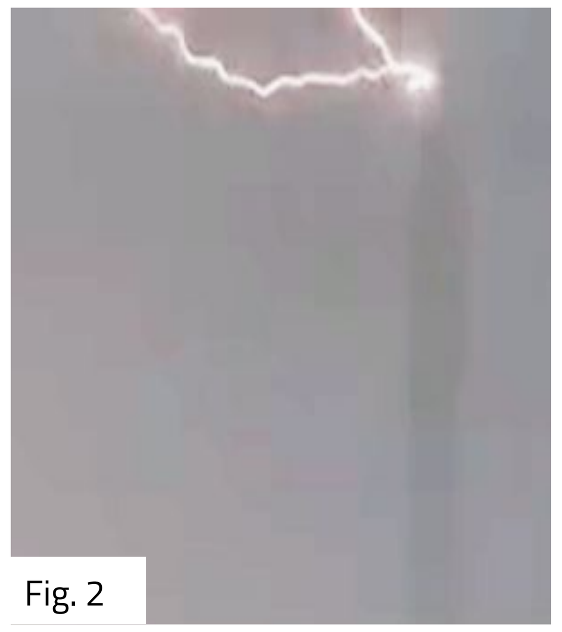

Fig. 2

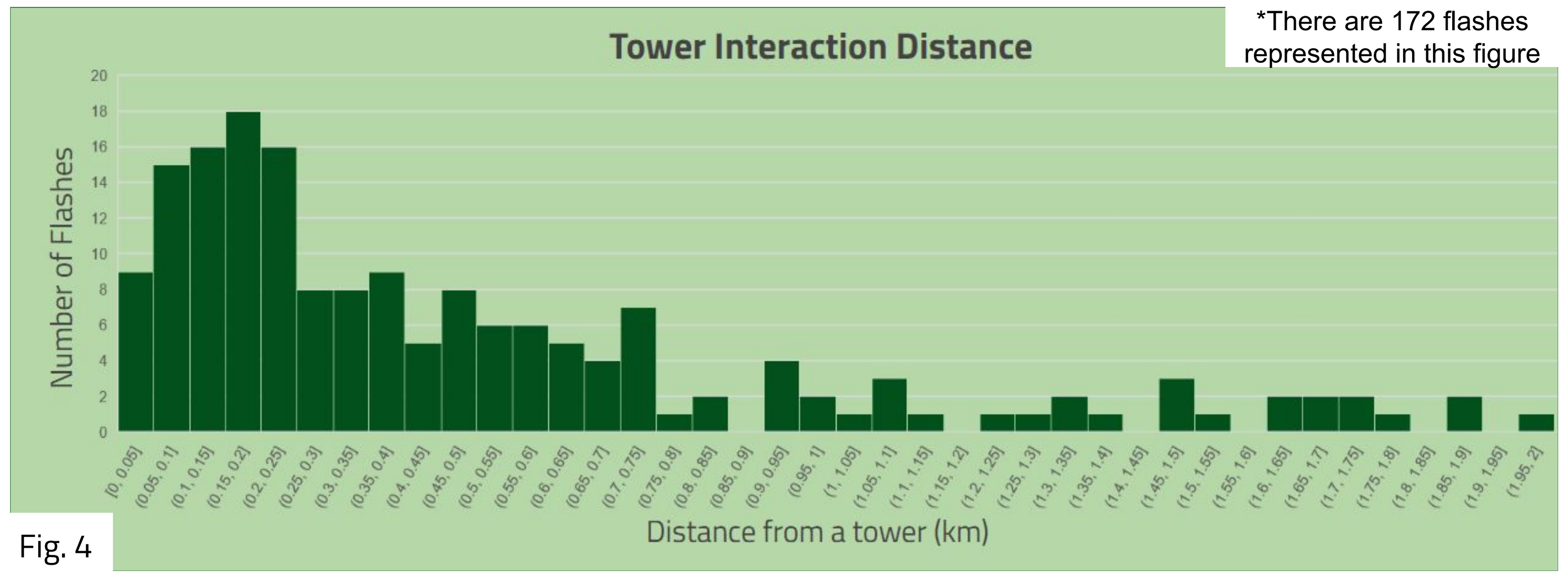

Fig. 4

Figure 4: Number of flashes compared to the distance between a man-made tower (as marked by the FAA) and the initial point of each flash. Strong association to tower is <0.100km, a weaker association between 0.100km and 0.300km, and little-to-no association >0.300km. Any events farther from 1km don't seem to have any association.

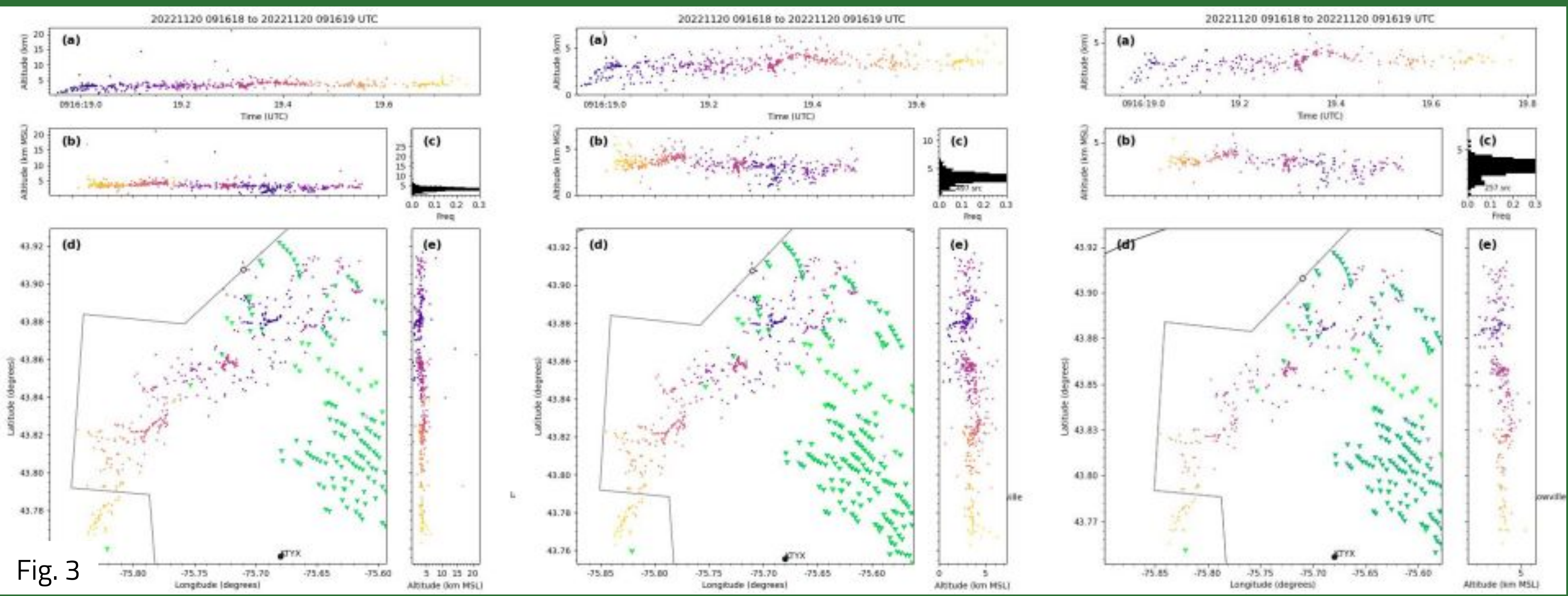

Fig. 3

Conclusions

- The best LMA station min. value when detecting flashes is 6.
- The concentration of lightning during lake-effect storms has shifted from over Lake Ontario to the Tug Hill turbine fields (Steiger et al. 2018 and this study).
- We associate a flash with a tower if initial sources are within 0.100km of the tower.
- There is a notable error in altitude LMA solutions when lightning occurs far (>50 km) from the network.

Acknowledgments

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References are available upon request.