An Analysis of Events with a Significant Surface Vertical Electric Field in Barrow, Alaska

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Research Questions

- How many significantly electrified events occur in Barrow, Alaska?
- What time of year do these events occur?
- What situations cause significant surface vertical electric fields (Ez)

Instrumentation

- 2 CS110 Electric Field Mills deployed at Barrow, Alaska
- Vertical Pointing Ka-Band Radar at DOE NSA ARM site
- Temperature profiles from radiosondes and ERA5 reanalysis

Methodology

- Overlay Ez with collocated vertical pointing radar for case studies.
- Create daily and composite 2-dimensional histograms comparing reflectivity to temperature and Ez.
- Compare WWLLN detected lightning to localized spikes in Ez

Table 1: Number of events that occurred where maximum Ez is greater than specified thresholds.

Max V/m	# of Events
2000	92
5000	44
10000	26
20000	6

Table 2: Percent occurrence of significantly electrified events (Ez > 2,000 V/m) for different vertical temperature profiles.

Temperature (°C)	% Occurrence
Surface > 0	76%
Entire Column < 0	18%
Surface < 0 & Column > 0	6%

Occurrence of Events

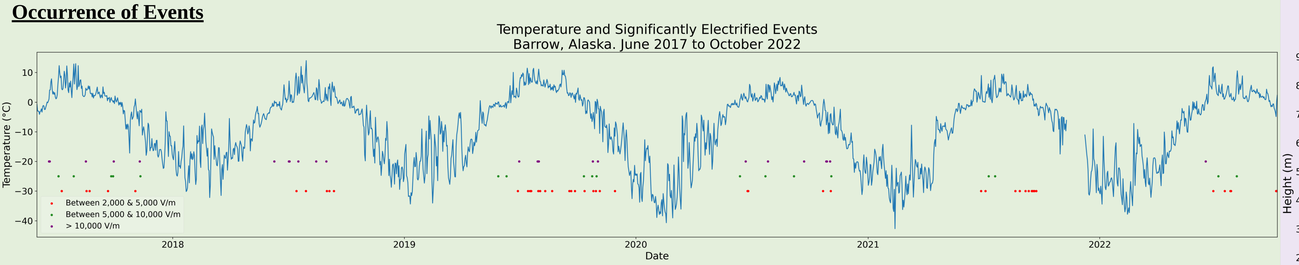

Figure 1: Time series of daily mean surface temperatures plotted from June 2017 to October 2022 with significantly electrified event days plotted as dots corresponding to the day that they occurred. Different dot colors represent the range of maximum Ez reached for each event day.

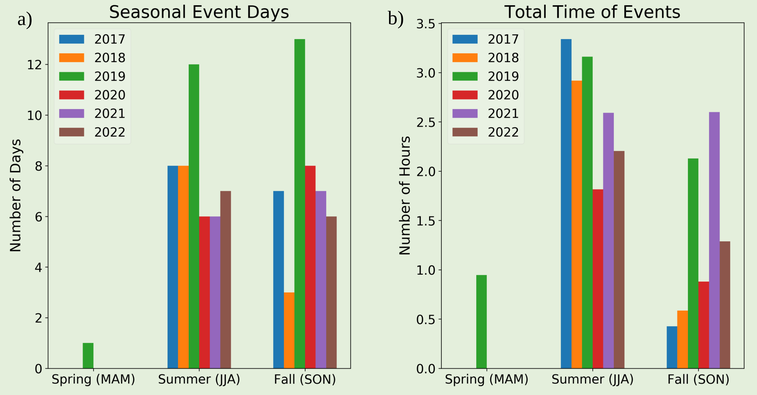

Figure 2: a) Number of days with a significant Ez event > 2,000 V/m categorized seasonally for each year. b) Total time that Ez was greater than 2,000 V/m for each season of each year.

- Of all 92 cases, only 1 case occurs in the spring. This event is in 2019, the most active year by number of days and total duration of events. The total time for this single event is greater than the 2017 and 2018 Fall total times combined, indicating a long event.
- 2021 and 2022 have the same number of event days (13), however; 2021 has 1.7 hours more total time than 2022 (5.2 vs 3.5). This shows that, on average, the majority of cases in 2021 were longer than 2022.
- The total time of Fall cases is consistently less than or equal to the total time of Summer cases for the same year. The total days does not have the same correlation, showing that the Summer cases are generally longer events than the Fall cases.

Lightning near Barrow?

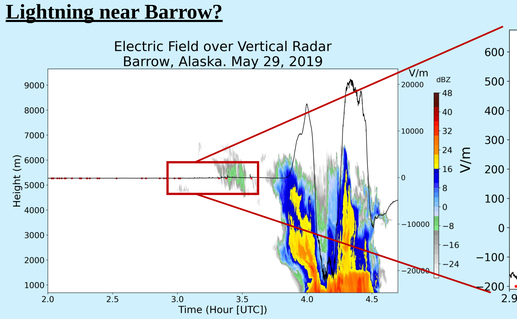

Figure 4: Ez overlaid over vertical pointing radar with collocated WWLLN detected lightning.

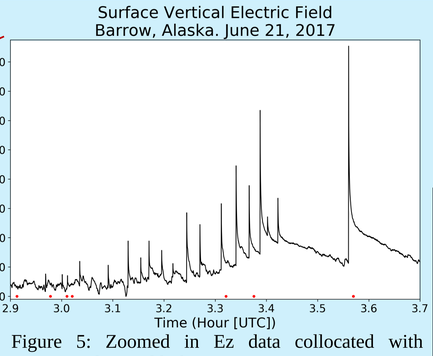

Figure 5: Zoomed in Ez data collocated with WWLLN detected lightning.

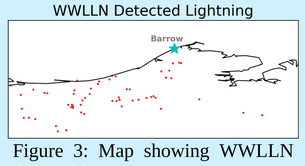

Figure 3: Map showing WWLLN detected lightning near Barrow

- Spikes in Ez followed by a "recharge" are clear indications of lightning.
- Some strikes are detected by WWLLN, and some are not.
- No significant Ez is found in Barrow from the distant lightning.

Properties of Events

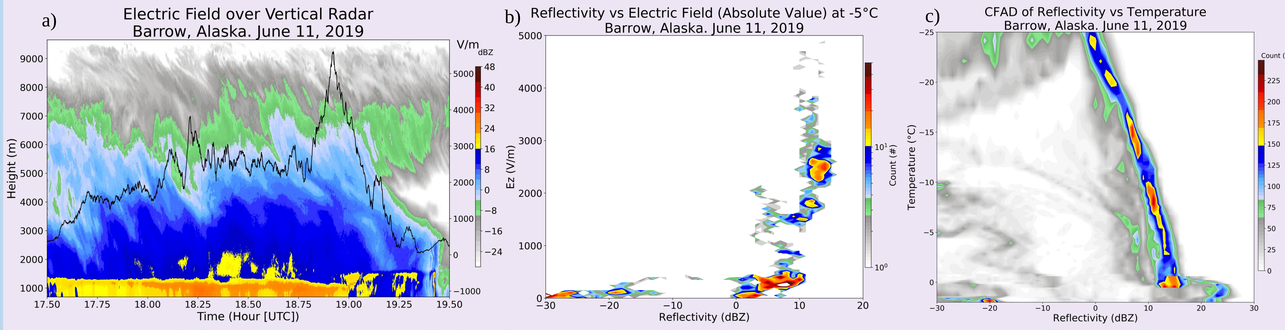

Figure 6: Case Study for June 11, 2019. a) Vertical radar reflectivity overlain with Ez. b) 2-dimensional histogram comparing reflectivity values at -5°C (2500m) to the absolute value of Ez at the collocated time. c) CFAD comparing all reflectivity and vertical temperature values.

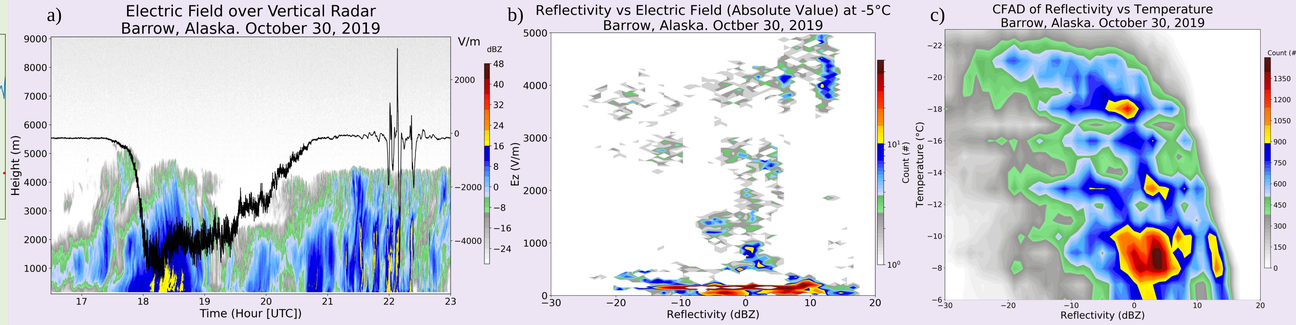

Figure 7: Case Study for October 30, 2019. a) Vertical radar reflectivity overlain with Ez. b) 2-dimensional histogram comparing reflectivity values at -5°C (900m from 16-21 UTC and 1100m after 21 UTC) to the absolute value of the còllocated Ez. c) CFAD comparing reflectivity and temperature values.

Figure 6: June 11, 2019

- Ez consistently > 2,000 V/m from 18 to 19 UTC.
- The bright band at the melting layer between 0°C and 4°C is clearly visible on the radar in Figure 6a and by the jump to significantly higher reflectivity values at these temperatures in Figure 6c.
- Figure 6b shows that Ez does not become significant until reflectivity values are at least 10 dBZ at -5°C.

Figure 7: October 30, 2019

- Large deviations in Ez due to changes in environmental temperature.
- Snowfall corresponds to reflectivity values where Ez is significantly negative and the precipitation changes to rain at 21 UTC when the surface temperature reaches above freezing.
- Ez appears inconsistent in Figure 7b due to lower reflectivity values during periods of snow corresponding to significant negative values.

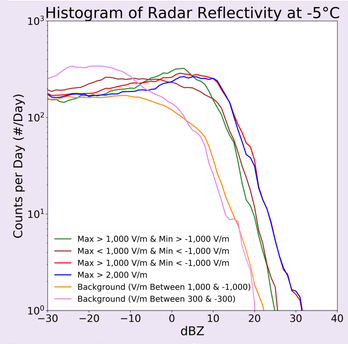

Figure 8: Histogram showing counts per day of radar reflectivity at -5 °C for different days with varying maximum Ez.

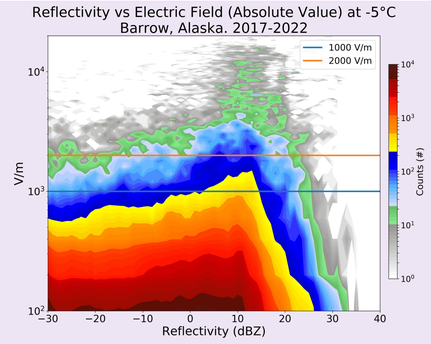

Figure 9: Composite 2-dimensional histogram comparing reflectivity at -5°C to Ez for all event days. Plotted with a logarithmic Y-scale.

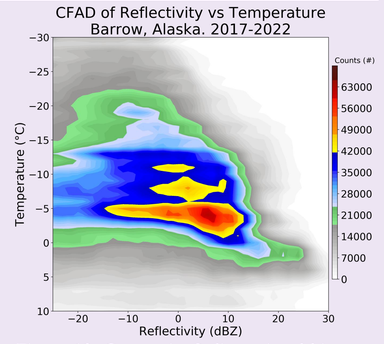

Figure 10: Composite 2-dimensional histogram comparing radar reflectivity to temperature for all event days.

- Events with maximum Ez > 2,000 V/m have higher counts of higher reflectivity at the -5°C height level compared to background "fair weather" days and events that were only significantly positive or negative as indicated by the green and brown lines in Figure 8.
- 3 groupings of lines are seen in Figure 8 as they approach higher reflectivity values. The blue and red lines are considered the convective grouping due to consistently higher reflectivity at -5°C. Figure 9 shows that 0 dBZ at -5°C is generally required for highly electrified cases.
- The composite CFAD in Figure 10 shows a bullseye between 0 and 10 dBZ and -5°C, showing consistent features between the Ez events. A bright band is seen in the melting layer between 0°C and 4°C as a sharp increase in reflectivity values in that temperature range.

Acknowledgement

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Summary

Ninety-two days recorded Ez values of greater than 2,000 V/m between 2017 and 2021. Lightning occasionally occurs in Barrow; however, no cases were recorded with lightning within the Ez bounds of the research. All but one of these events occur in meteorological summer and fall, with summer events being longer on average. Convective storms require at least 0 dBZ at -5°C, showing charge separation from the liquid and ice particles in the mixed phase region that cause Ez to be greater than 2,000 V/m.