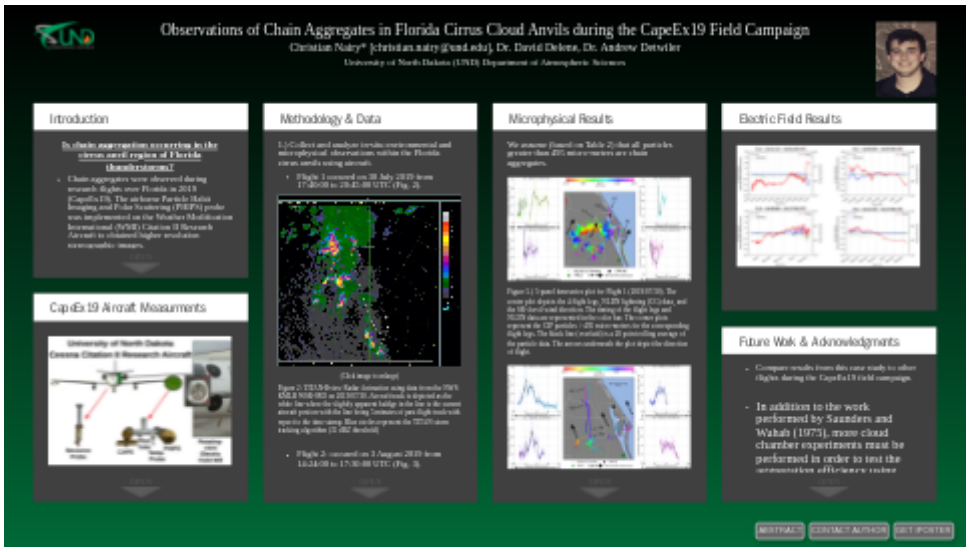
Observations of Chain Aggregates in Florida Cirrus Cloud Anvils during the CapeEx19 Field Campaign



Christian Nairy* [christian.nairy@und.edu], Dr. David Delene, Dr. Andrew Detwiler

University of North Dakota (UND) Department of Atmospheric Sciences

PRESENTED AT:

INTRODUCTION

Is chain aggregation occurring in the cirrus anvil region of Florida thunderstorms?

- Chain aggregates were observed during research flights over Florida in 2019 (CapeEx19). The airborne Particle Habit Imaging and Polar Scattering (PHIPS) probe was implemented on the Weather Modification International (WMI) Citation II Research Aircraft to obtained higher resolution stereographic images.

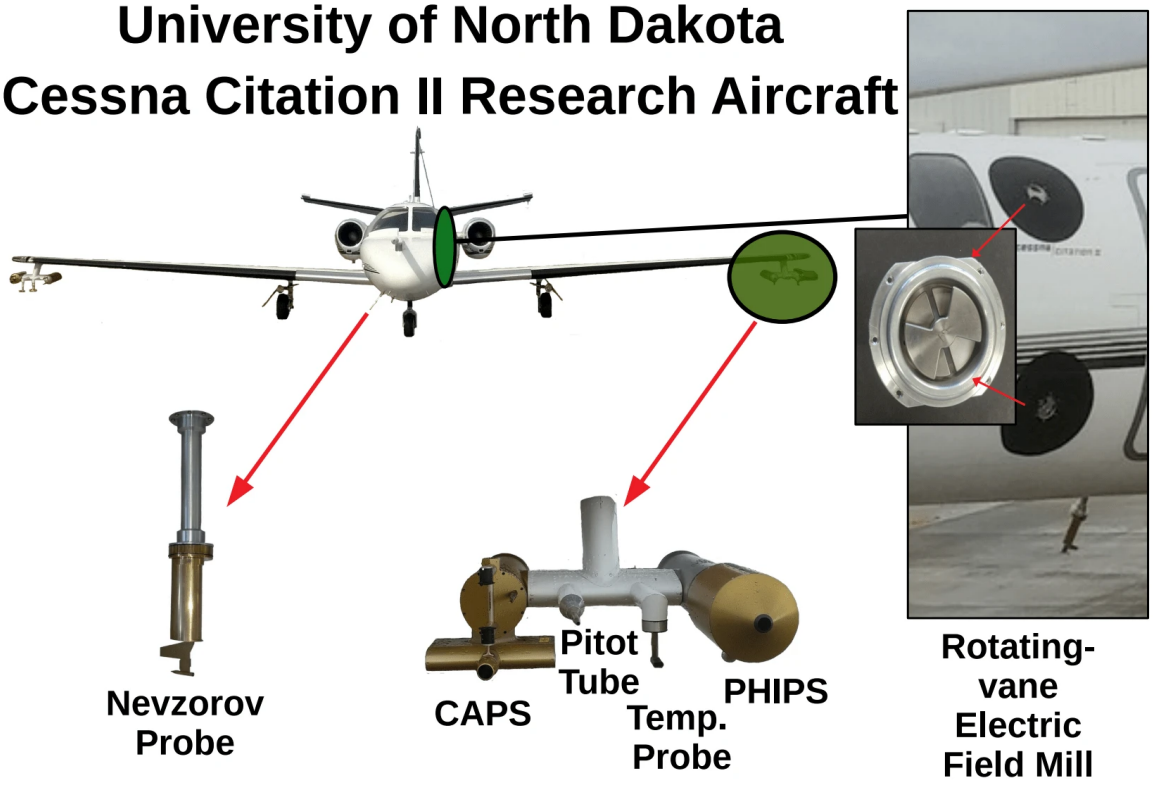
- Surface radar and aircraft instrumentation are utilized to determine the location and characteristics of the chain aggregates.

- In cloud chamber experiments[1], chain aggregates were generated near the -10 °C level and also when electric fields were above 70 kV/m.

- **Determining the process which generate these large chain aggregates in cirrus cloud anvils should enable models to predict their occurrence.**

- **Implementing chain aggregates in models should provide increased knowledge for the radiative impacts of cirrus anvils[2] as well as for militaristic applications such as projectile re-entry impacts.**

CAPEEX19 AIRCRAFT MEASURMENTS



(Click image to enlarge)

Figure 1.) The WMI Citation II Research Aircraft[2] contains a wide variety of instrumentation, though, the instruments depicted in the figure above were utilized the most pertaining to this study.

- The airborne Particle Habit Imaging and Polar Scattering (**PHIPS**) probe was implemented to obtained higher resolution stereographic images and simultaneous measurement of the polar angular-light-scattering function of individual ice particles.

- The CAPS is a “multi-probe” that measures cloud and aerosol concentrations and records cloud particle images by utilizing a suite of three instruments. The three instruments included in the CAPS are the Cloud Imaging Probe (CIP), the Cloud and Aerosol Spectrometer (CAS), and the Hotwire Liquid Water Content Sensor.

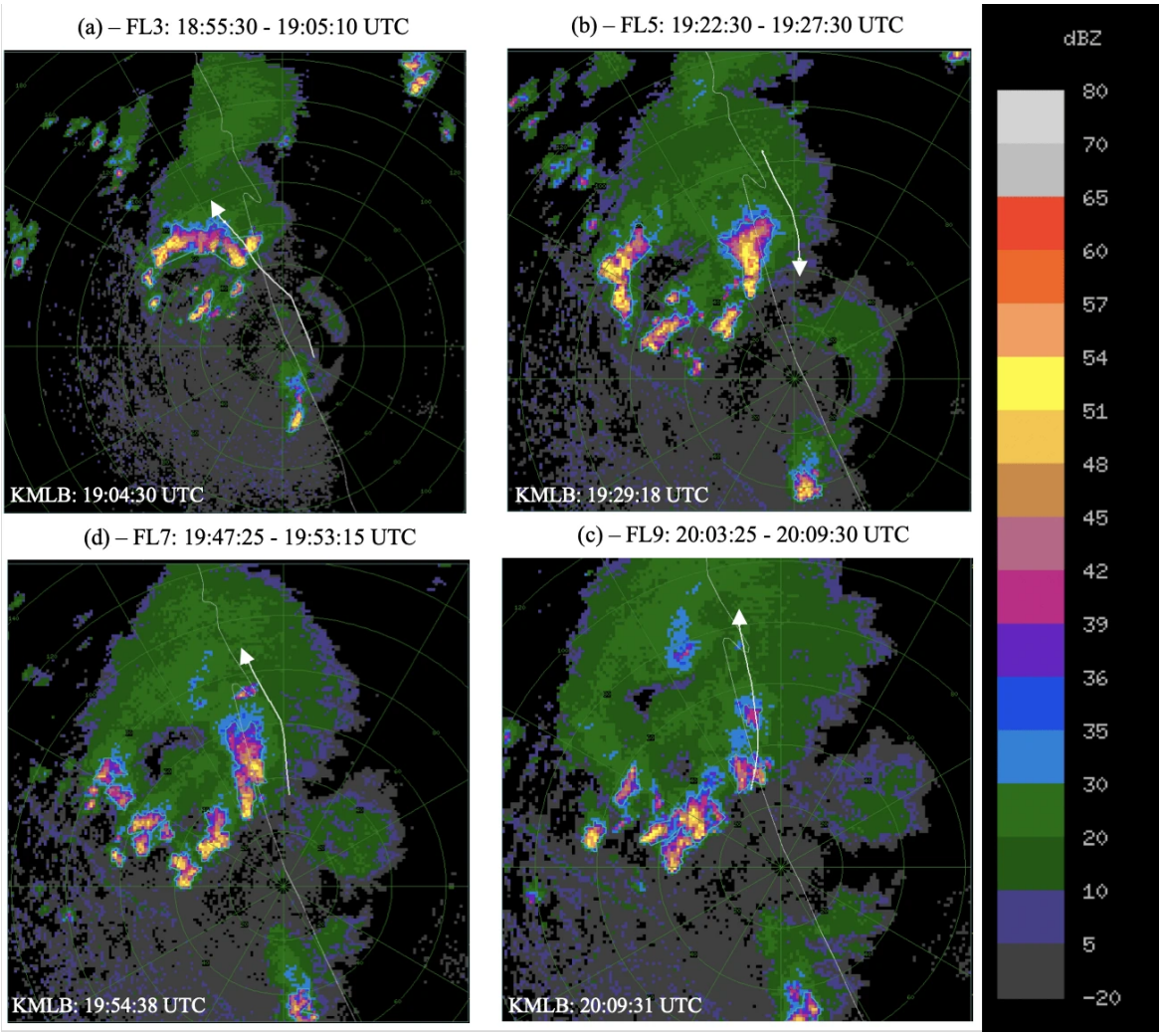
- 6 Rotating-vane Electric Field Mills were utilized for measuring electric field.

METHODOLOGY & DATA

1.) Collect and analyze in-situ environmental and microphysical observations within the Florida cirrus anvils using aircraft.

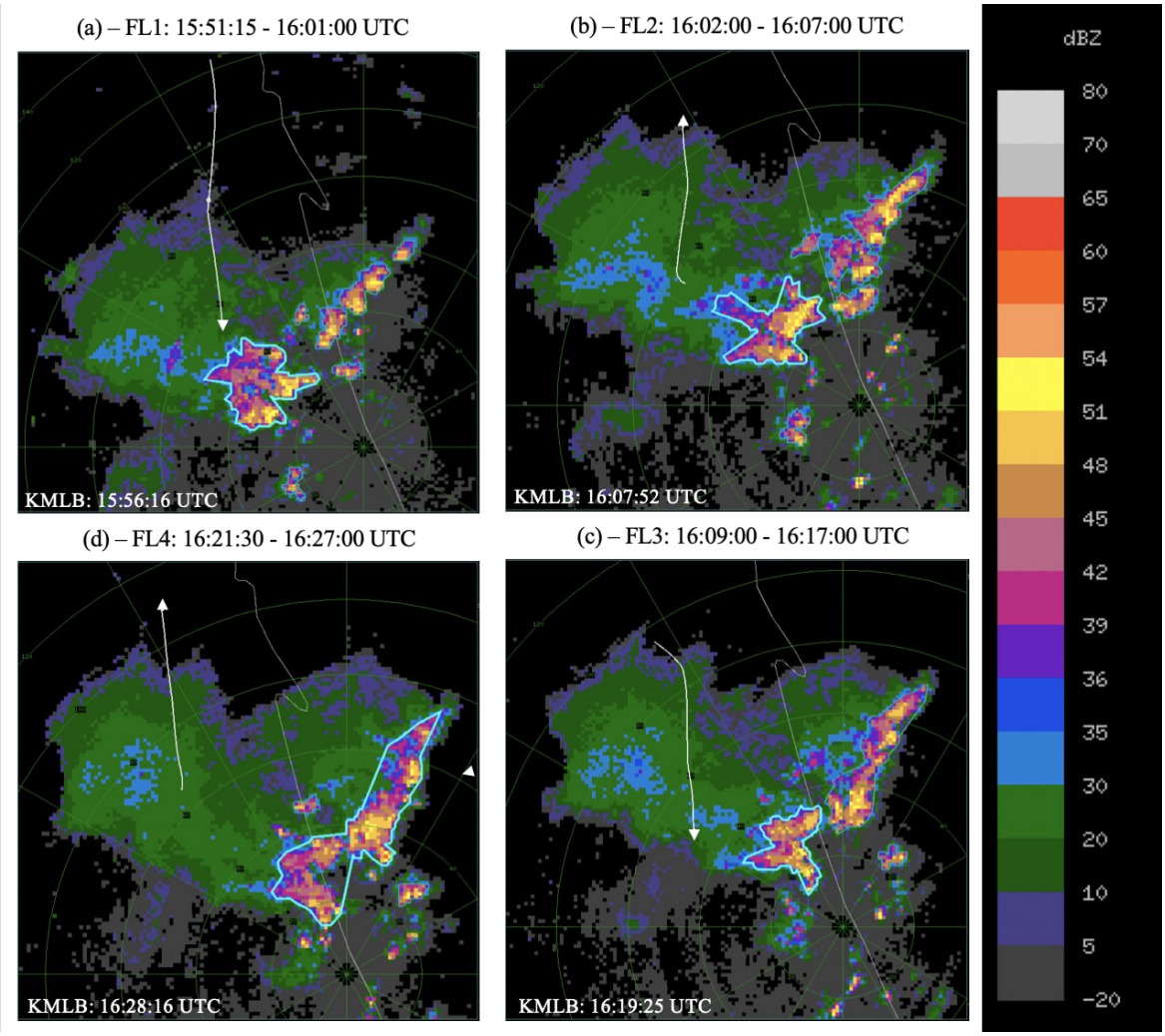
- Flight 1 occurred on 30 July 2019 from 17:40:00 to 20:45:00 UTC.
- Flight 2: occurred on 3 August 2019 from 14:24:00 to 17:30:00 UTC.

2.) Define individual flight legs (FL's) for both flights where the Citation II was traveling relatively straight, at a constant altitude, and sampling cirrus anvil clouds.



(Click image to enlarge)

Figure 2: TITAN-Rview Radar using data from the NWS KMLB WSR-88D on 2019/07/30. Aircraft track and direction of flight is depicted as the white line and arrow. The aircraft was sampling at around 11 km AGL for the FL's

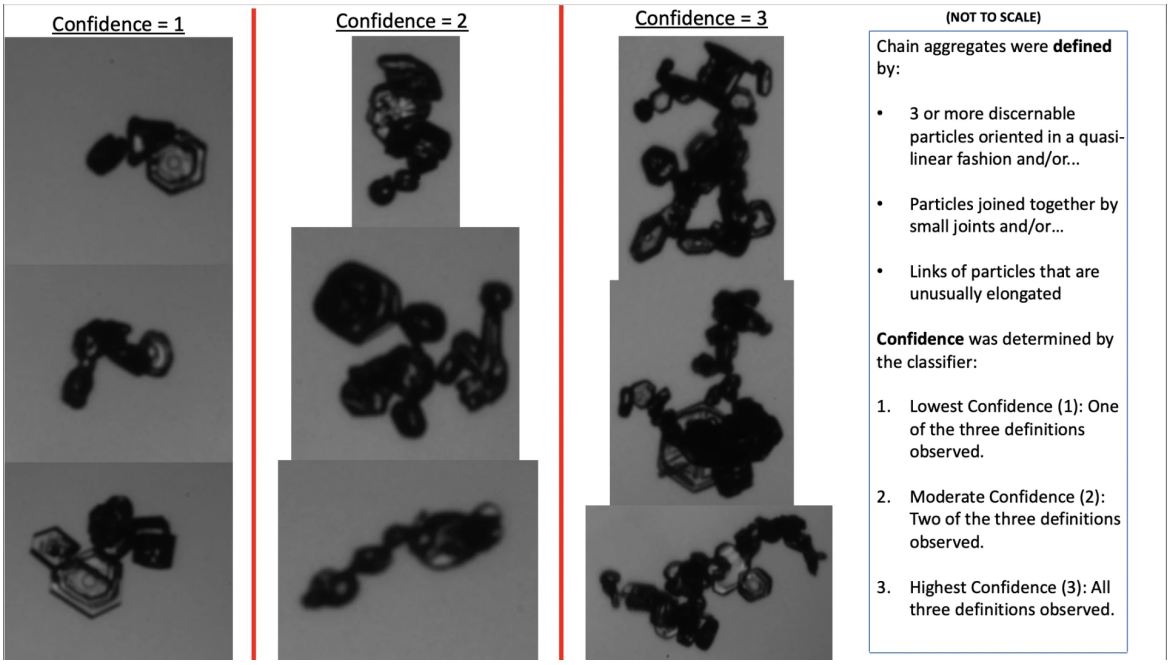


(Click image to enlarge)

Figure 3: Same as in Figure 2 but for the flight on 2019/08/03. This figure also includes storm core (in bold blue) outlines. The aircraft was sampling at around 10 km AGL for the FL's

3.) PHIPS classification software was used to manually classify the PHIPS images taken during Flight 2 (2019/08/03).

- Due to the inhomogeneity of the observed chain aggregates from the CapeEx19 flights, the confidence selector within the PHIPS classification software was utilized in the new definition. Thus, the new definition is not Boolean in nature but can range in confidence (Figure 4).



(Click image to enlarge)

Figure 4: Image showing chain aggregates with varying confidence. Definitions are depicted on the right hand side of the figure.

Table 1: PHIPS data chart depicting the amount of chain aggregates during Flight legs 1-4 during Flight 2 (2019/08/03) with respect to distance from storm core reflectivity centroid.

	# of Chains Found 100 - 70 km From Storm Core	# of Images Taken 100 - 70 km From Storm Core	# of Chains Found 70 - 40 km From Storm Core	# of Images Taken 70 - 40 km From Storm Core	# of Chains Found 40 - 10 km From Storm Core	# of Images Taken 40 - 10 km From Storm Core
FL1	58	510	123	629	37	367
	11.4%		**19.6%**		**10.1%**	
FL2	N/A	N/A	78	520	40	397
	N/A		**15.0%**		**10.1%**	
FL3	18	55	118	779	55	541
	32.7%		**15.1%**		**10.2%**	
FL4	44	178	93	677	N/A	N/A
	24.7%		**13.7%**		**N/A**	

- If chain aggregates are formed in the cores of the storms, it's expected that we should see more chains closer to the core than away. The PHIPS data does not show that this is the case.

Table 2: PHIPS data table from Flight 2 (2019/08/03) showing the amount of particles and chain aggregates sampled that were greater-than 495 micro-meters. The confidence values coincide with the observed/classified chain aggregates.

20190803_1424 Flight Legs	# of PHIPS Particles > 495 um	# of PHIPS Chains > 495 um	$\frac{\#\ of\ PHIPS\ Chains\ >\ 495\ um}{\#\ of\ PHIPS\ Particles\ >\ 495\ um}$	Avg. Confidence of PHIPS chains > 495 um
Flight Leg 1	17	14	82%	2.78
Flight Leg 2	16	13	81%	2.31
Flight Leg 3	21	17	81%	2.41
Flight Leg 4	14	11	79%	2.0
TOTAL	**68**	**55**	**81%**	**2.375**

4.) A high percentage (81%) of the PHIPS images that contained particles > 495 micro-meters were chain aggregates. Thus, we can look at the CIP data (which has a higher sampling volume than the PHIPS) and pull the concentration of particles > 495 micro-meters.

5.) Utilize electric field mill measurements to decipher if the electric field is strong enough to encourage chain aggregation in the cirrus anvil(s).

MICROPHYSICAL RESULTS

It is assumed (based on Table 2) that all particles greater than 495 micro-meters are chain aggregates.

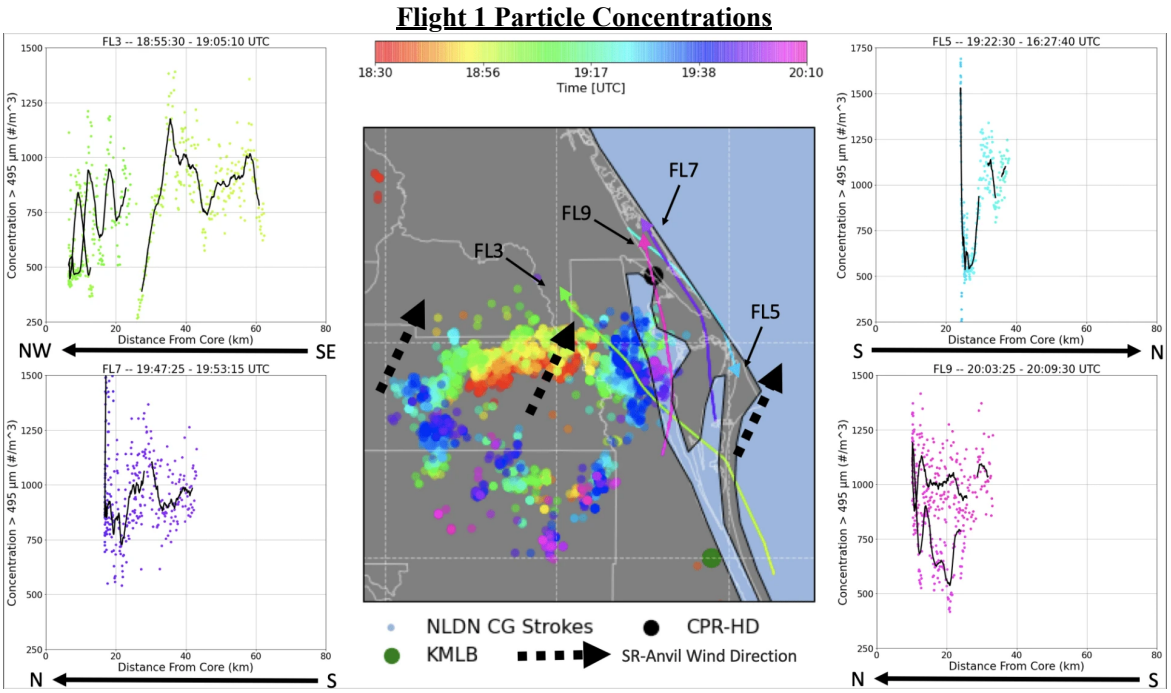


Figure 5.) 5-panel timeseries plot for Flight 1 (2019/07/30). The center plot depicts the 4 flight legs, NLDN lightning (CG) data, and the SR-Anvil wind direction. The timing of the flight legs and NLDN data are represented in the color bar. The corner plots represent the CIP particles > 495 micro-meters for the corresponding flight legs. The black line (overlaid) is a 20-point rolling average of the particle data. The arrows underneath the plot depict the direction of flight.

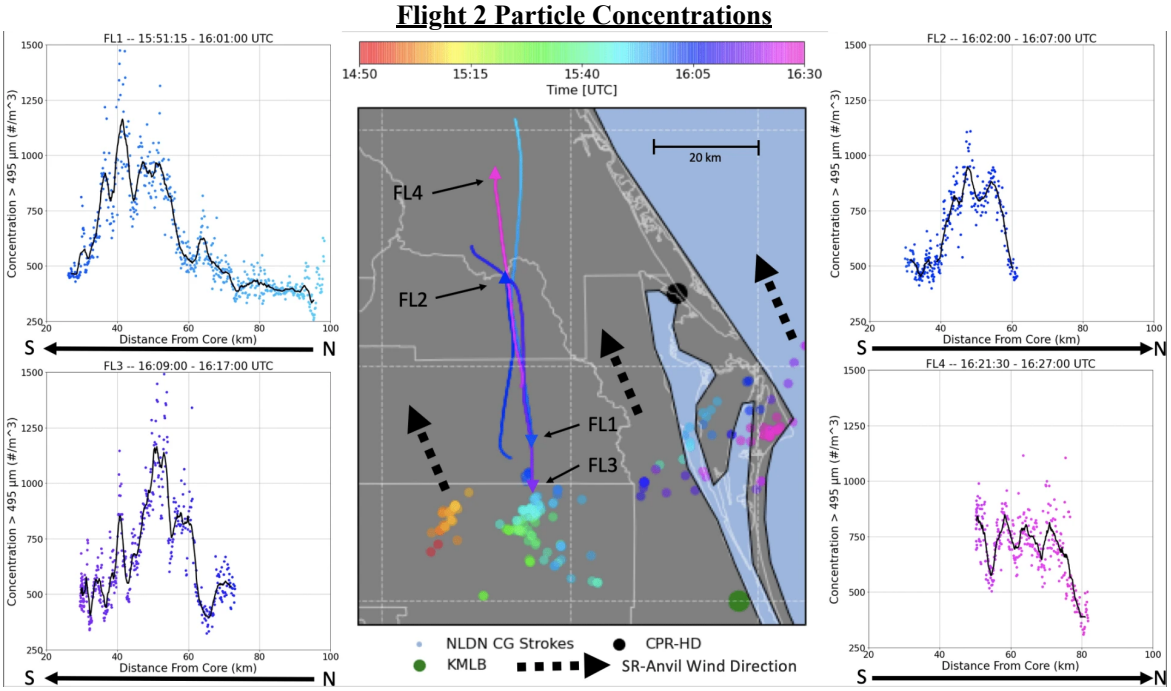


Figure 6.) Same as figure 5 but for Flight 2 (2019/08/03)

- If chain aggregates were formed near/around the storm core, we should see higher particle concentrations as the aircraft approached the storm core. Figs 5 & 6 shows that this was not always the case which agrees with Table 1.

- Periodicity of particle concentrations > 495 micro-meters is also observed.

ELECTRIC FIELD RESULTS

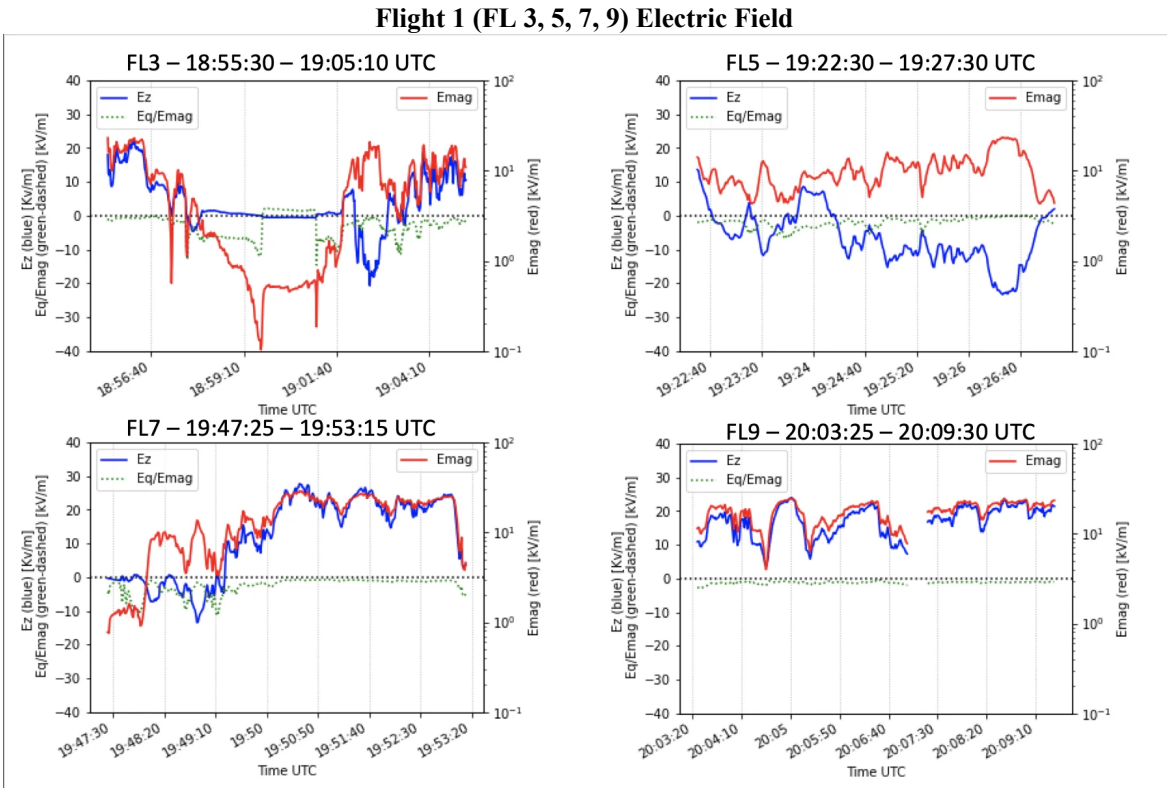


Figure 8.) Electric field data from flight legs 3, 5, 7, and 9 from Flight 1 (2019/07/30). Ez, is the vertical component of electric field (blue line) and Eq/Emag (dotted green line) is the measure of the field due to charge on the aircraft. Both are referenced to the linear scale on the left. Emag, is the scalar magnitude of the vector field (red line) and is referenced to the log scale on the right side of the panel.

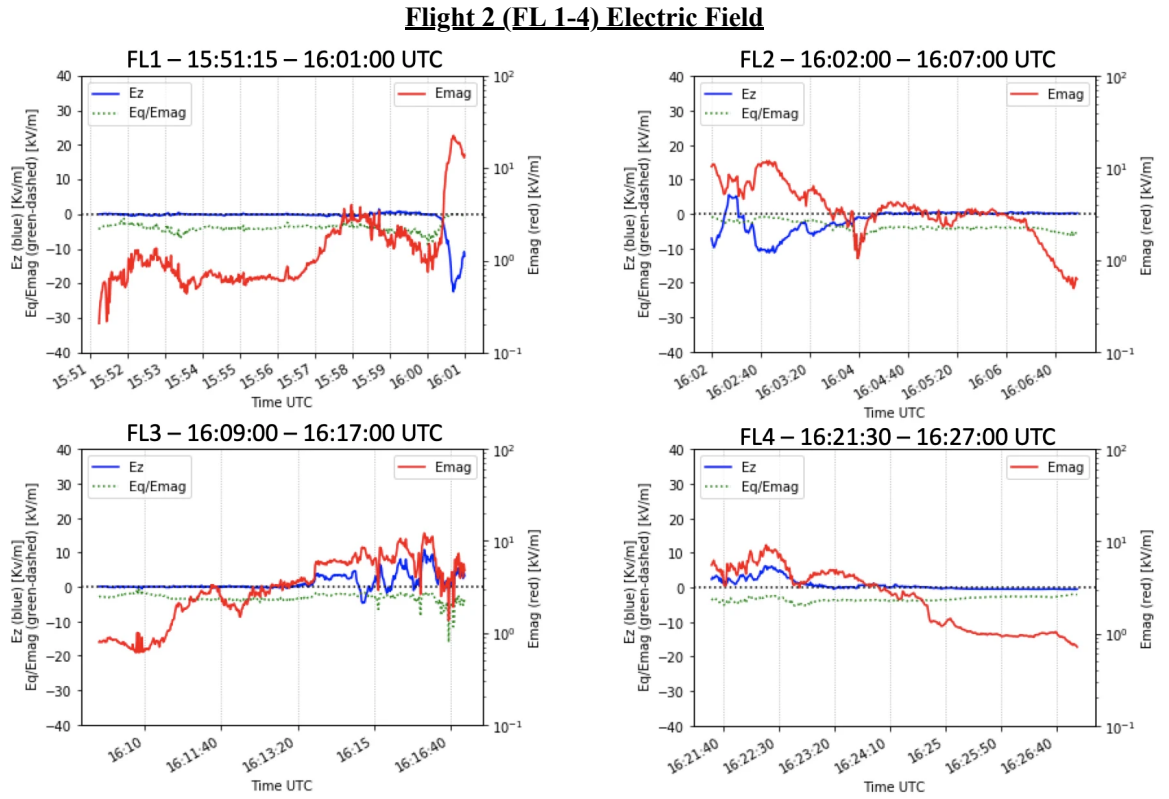


Figure 9.) Same as Figure 8 but for flight legs 1-4 for Flight 2.

- The electric field magnitudes for both flights never surpass the 70 kV/m threshold (as depicted in Saunders and Wahab, 1975). However, in some FL's the electric field magnitudes are relatively high for cirrus anvil regions.

Kennedy Space Center Lightning Mapping Array Data

[VIDEO] https://res.cloudinary.com/amuze-interactive/image/upload/f_auto,q_auto/v1639413335/agu-fm2021/eb-00-09-d7-b9-a1-1b-64-c6-9f-c8-60-ee-ee-de-8f/image/lma_1601_event_animation_latlon_eduvoz.mp4

Figure 10.) Kennedy Space Center Lightning Mapping Array (KSCLMA) data showing a lightning event (animation) during Flight 2 shortly after FL1.

- A possibility for chain aggregation could be the lightning discharges themselves. The LMA data shows that levels above 10 km AGL are electrically active (upper + charge region).

Flight 2 (FL1) Electric Field Vectors (Emag)

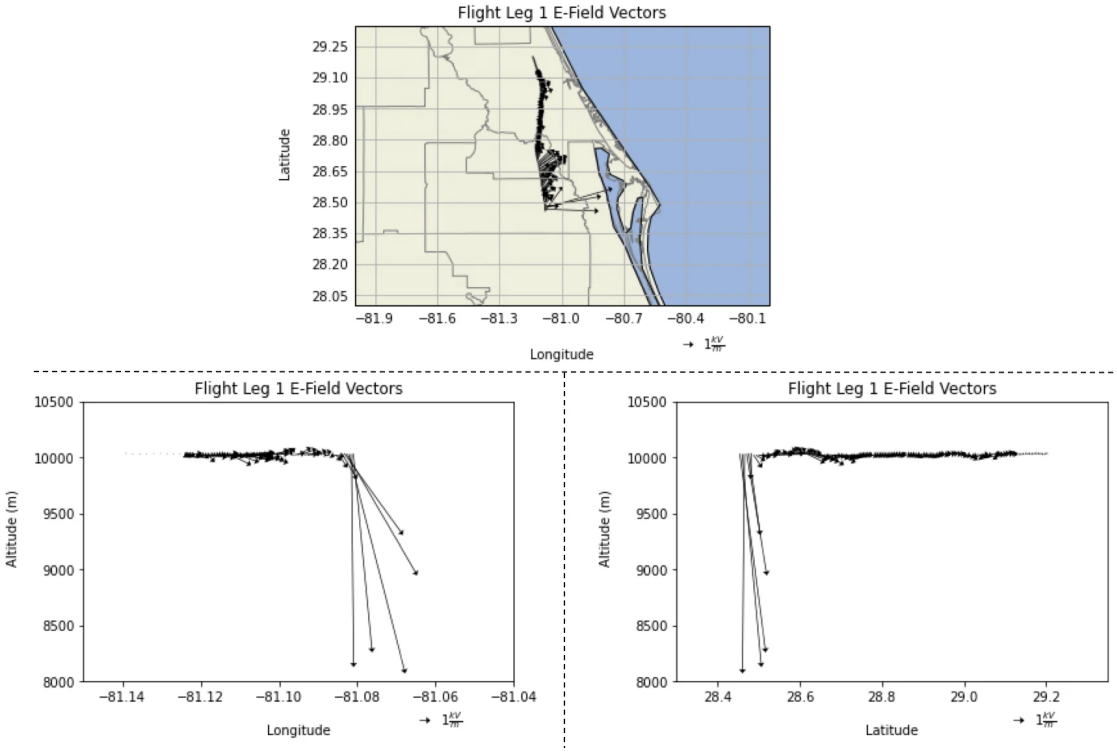


Figure 11.) Electric field vectors (Emag) for FL1 during Flight 2. Top panel shows the X-Y (lat-lon) vector orientation. Bottom left panel shows the X-Z (lon-alt) vector orientation. Bottom right panel shows the Y-Z (lat-alt) vector orientation.

- The electric field vector plots for FL1 show that the charge in the upper portion of the storm is postively charged.
- Also, these plots show that the convective cores are often associated with higher electric fields.

FUTURE WORK & ACKNOWLEDGMENTS

- Compare results from this case study to other flights during the CapeEx19 field campaign.

- Look for correlations between the electric field data and the periodicity found in the CIP particles > 495 micro-meter concentrations.

- Look for correlations between the amount of electrical discharges and the concentration of particles > 495 micro-meters found in the cirrus anvil region.

- In addition to the work performed by Saunders and Wahab (1975), more cloud chamber experiments must be performed in order to test the aggregation efficiency using lower electric fields and at colder temperatures (between -40 and -30 °C.)

- This Research is supported by a Naval Surface Warfare Center Dahlgren Division grant to conduct and analyze data from the CapeEx19 field project.

- The authors would like to thank Martin Schnaiter and Emma Järvinen for the PHIPS data and PHIPS classification software.

- Also, we would like to thank Michael Poellot, Jerome Schmidt, and Paul Harasti for their guidence and knowledgeable input on this study.

AUTHOR INFORMATION

CHRISTIAN NAIRY
3904 University Ave., Apt. 223 – Grand Forks, ND 58203 – (585) 545-8785 – christian.nairy@und.edu

EDUCATION

Undergraduate, *Meteorology B.S. – minor in mathematics*
State University of New York (SUNY) College at Oswego
Graduated: May 2019
GPA: 2.92
Graduate, *Atmospheric Science M.S.*
University of North Dakota – John D. Odegard School of Aerospace Sciences
Expected Graduation Date: May 2022
GPA: 3.79

WORK EXPERIENCE

Webster Central School District Buildings and Grounds - 119 South Ave., Webster, NY 14580
-Heating, Ventilation, and Air Conditioning/Refrigeration (HVAC/R) Technician - Summer 2015 - 2019

- Performed duties ranging from heating and cooling split-systems, dismantling boilers, and fixing refrigeration systems.

Supervisor: Blaine Cunningham (Blaine_Cunningham@webstercsd.org)

- Phone: (585) 265-6585

Storm Forecasting and Observation Program (SUNY Oswego Storm Chasing) - 7060 NY-104, Oswego, NY 13126
-Driver & Assistant Forecaster - May 2018 – June 2018

- Responsible for driving students and providing forecasts to help predict the best possible storm chase location.
- Created a short movie using Adobe Premiere Pro depicting our experiences throughout the trip.

Supervisor: Dr. Scott Steiger (scott.steiger@oswego.edu)
Phone: (315) 312-2802

Lake-Effect Storm Prediction and Research Center (LESPaRC) - 7060 NY-104, Oswego, NY 13126
-Forecaster - October 2018 - March 2019

- Provided detailed forecasts and snowfall map analysis for the New York Department of Transportation (NYDOT).

President: Dr. Scott Steiger (scott.steiger@oswego.edu)

University of North Dakota - 4149 University Ave., Grand Forks, ND 58202
-Graduate Teaching Assistant (GTA) - August 2019 – December 2019

- Assisted Dr. Matthew Gilmore in Extreme Weather and Climate (ATSC220) comprised of 34 students.
- Assisted with lectures, creation of homework, quizzes, and tests, as well as proctoring.
- Assisted Dr. Mark Askelson in Synoptic Meteorology (ATSC411) comprised of 15 students.
- Performed duties such as in class lectures on Quasi-Geostrophic Theory as well as various other topics during the laboratory sections.
- Graded homework, quizzes, and forecast discussions.

Professor: Dr. Matthew Gilmore (matthew.gilmore@und.edu)

- Phone: (701) 777-3124

Professor: Dr. Mark Askelson (mark.askelson@und.edu)

- Phone: (701) 777-6880

-Graduate Research Assistant (GRA) - January 2020 - Present

- Assistant to Dr. David Delene working with aircraft and radar data collected during the CapeEx19 Field Project.
- Thesis topic: Observations of Chain Aggregates in Florida Cirrus Anvils
  - This study is being performed to further enhance our understanding of the various processes within electrified Florida thunderstorms for models and militaristic applications.

Advisor: Dr. David Delene (david.delene@und.edu)

- Phone: (701) 777-2184

INTERNSHIP EXPERIENCE

Naval Research Enterprise Internship Program (NRIEP) - Monterey, CA, Summer 2021
Advisor: Dr. Jerome Schmidt (jerome.schmidt@nrlmry.navy.mil)
Phone: (831) 242-0355
-Intern

- Helped set up various meteorological instruments at their newly acquired field site near the U.S. Naval Research Laboratory. Worked with Ka-band radar data as well as investigating chain aggregation within Florida cirrus cloud anvils. Presented research findings in front of Naval personal.

SKILLS

- Microsoft Office (Word, Excel, PowerPoint)
- Programming: Python, NCL, C++, IDL, MATLAB
- Scientific Software: LROSE, ADPAA, GR2-Analyst, BUFKIT, AWIPS II, WRF Model, GARP, ANGEL
- Libre Office (Writer, Calc, Impress)
- Linux, Mac OS, Windows
- Adobe Products: Premiere Pro, After Effects, Photoshop

CAMPUS INVOLVMENT

- SUNY Oswego Lacrosse Team '15 - '16
- Great Lakes Science Symposium (GLASS) '16 - '18
- AMS '19 - '20
- SUNY Oswego Meteorology Club
- UND 3-Minute Thesis '20
- AGU '20 - '21 (poster & oral presentations)

ABSTRACT

During the CapeEX19 field campaign in the summer of 2019 near Melbourne, Florida, the North Dakota Citation Research Aircraft observed chain-like aggregates of ice crystals in convection-induced cirrus anvils. Exactly where and how the chain aggregation process is occurring in the thunderstorm is still not well understood, which inhibits their representation in atmospheric cloud models. Cloud chamber experiments indicate that the cloud electric fields play an important role in the development in chain aggregates, as well as other microphysical parameters. CapeEx19 aircraft instruments included six Rotating-Vane Electric Field-Mills for in-situ electric field strengths, and the Particle Habit Imaging and Polar Scattering (PHIPS) probe for high resolution particle images and microphysical information of the particles. In addition to the electric field and PHIPS data, lightning data provided by the National Lightning Detection Network (NLDN) and the Kennedy Space Center Lightning Mapping Array (KSCLMA) enable documentation of thunderstorm electrical activity and charge structure. During the CapeEx19 field campaign, over 170,000 particle images from the PHIPS probe were taken where a large percentage of the particle images appear to be chain aggregates. In addition, some of the chain aggregates from the flights were comprised of pristine ice crystals from different temperature regimes with a lack of rimed ice. The observed chain aggregates from multiple flights were observed between 10 – 100 km from the storm cores within the cirrus anvil. Interestingly, the aircraft sampled electric field strengths greater than 10 kV/m in the cirrus anvils near the vicinity of convective storm cores during multiple flights. This implies that chain aggregation might be possible higher aloft in much colder temperatures within the thunderstorm. This sizable data set gathered during the CapeEx19 field campaign enables an investigation to answer the question do the microphysical properties/characteristics and amount of chain aggregates change with respect to the different storm environments with varying electrical activity. Moreover, the inquiry that chain aggregation is possible in the cirrus anvils near the vicinity of the convective storm cores is investigated.

REFERENCES

[1]Saunders, C. P. R., and N. M. A. Wahab, 1975: The Influence of Electric Fields on the Aggregation of Ice Crystals. Journal of the Meteorological Society of Japan, 53, 121–126, https://doi.org/10.2151/jmsj1965.53.2_121

[2]Liou, K. N., 1973: Transfer of Solar Irradiance through Cirrus Cloud Layers., J. Geophys. Res., 78, 1409–1418.