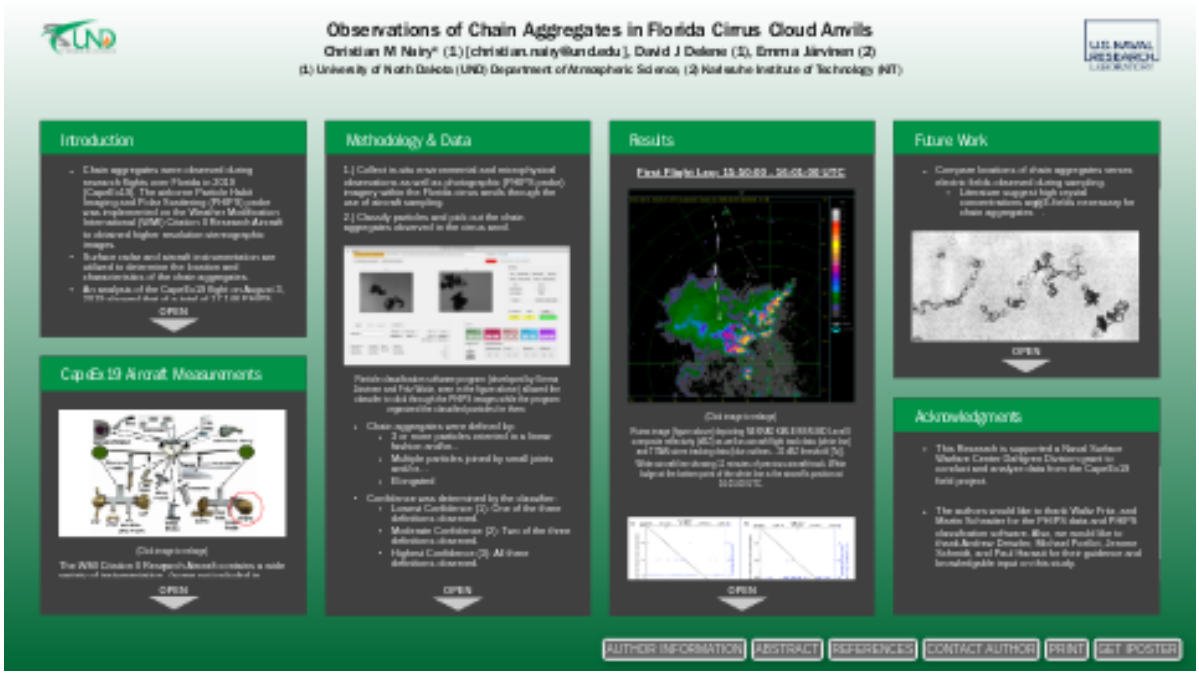
Observations of Chain Aggregates in Florida Cirrus Cloud Anvils



Christian M Nairy* (1) [christian.nairy@und.edu], David J Delene (1), Emma Järvinen (2)

(1) University of North Dakota (UND) Department of Atmospheric Science, (2) Karlsruhe Institute of Technology (KIT)

U.S. NAVAL RESEARCH LABORATORY

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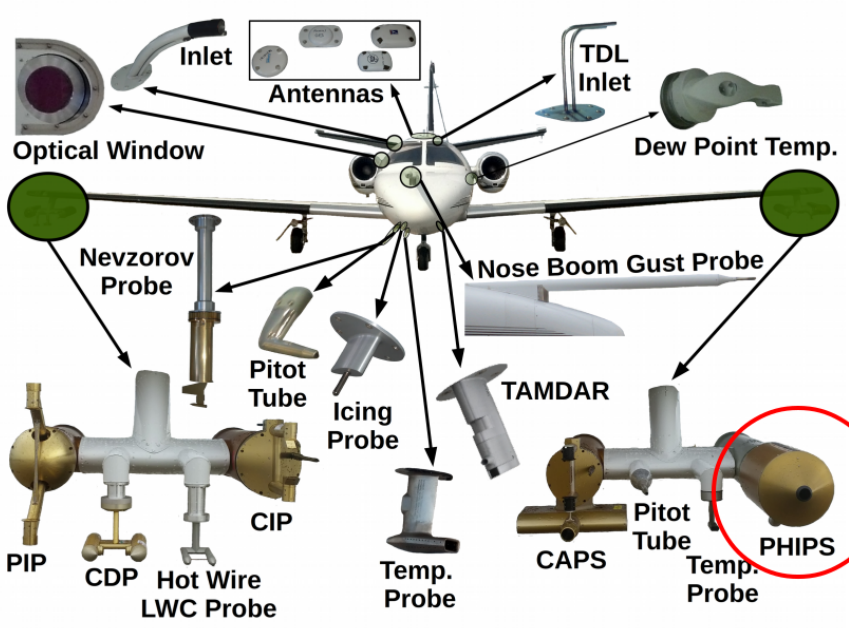
INTRODUCTION

- 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.
- An analysis of the CapeEx19 flight on August 3, 2019 showed that of a total of 17,146 PHIPS images, 7,151 where classified as chain aggregates.
- **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[1] as well as for militaristic applications such as projectile re-entry impacts.**

CAPEEX19 AIRCRAFT MEASUREMENTS



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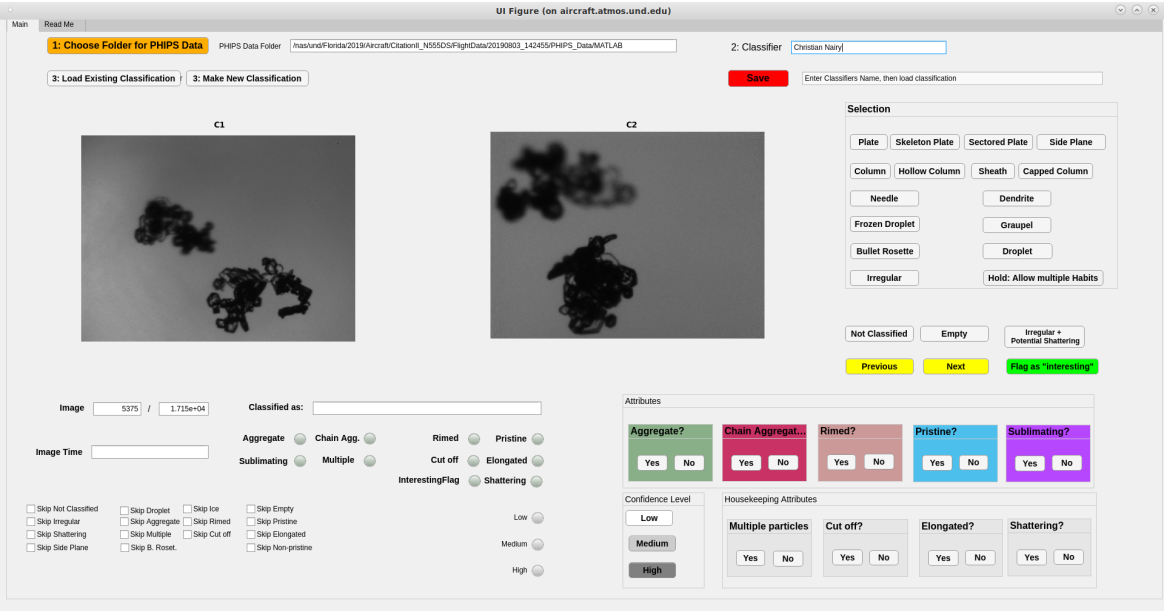
The WMI Citation II Research Aircraft contains a wide variety of instumentation[2] (some not included in figure above).

- **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[3].

METHODOLOGY & DATA

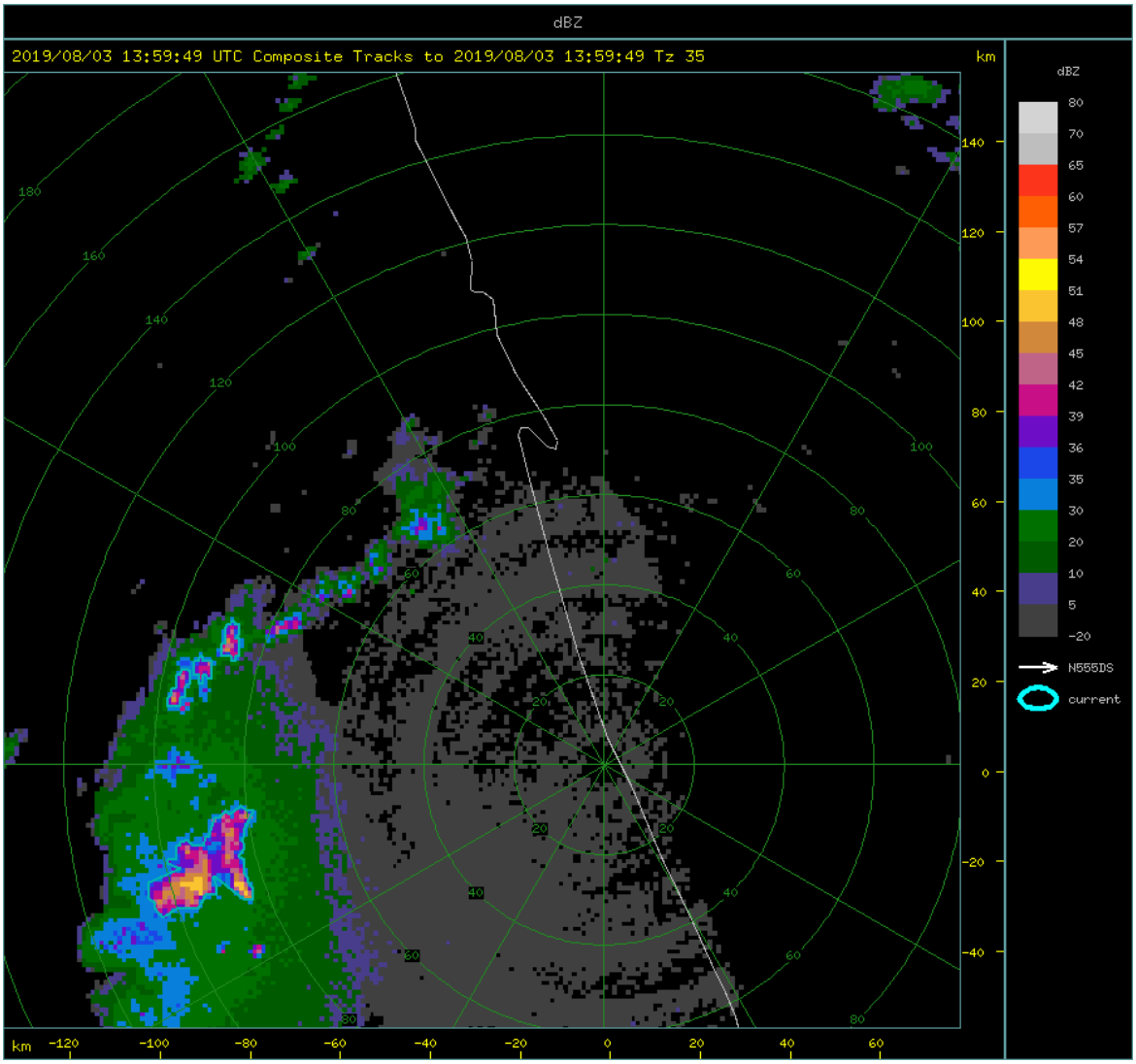
1.) Collect in-situ environmental and microphysical observations as well as photographic (PHIPS probe) imagery within the Florida cirrus anvils through the use of aircraft sampling.

2.) Classify particles and pick out the chain aggregates observed in the cirrus anvil.



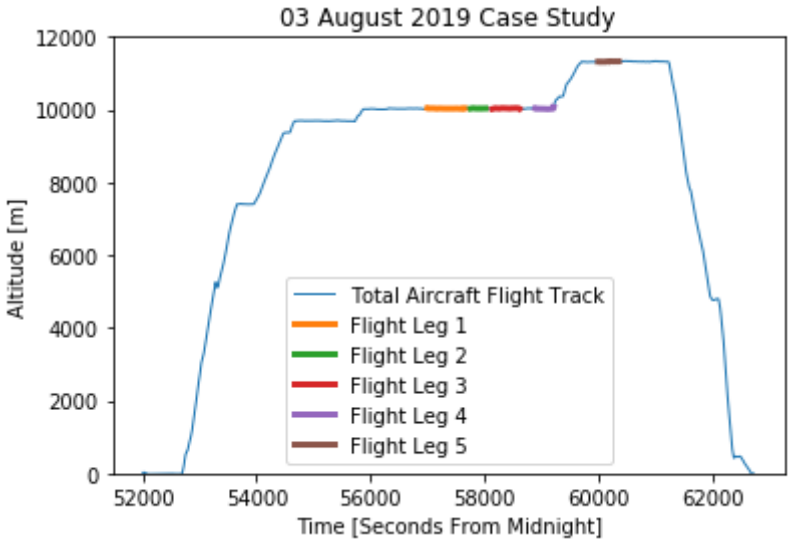
Particle classification software program (developed by Emma Järvinen and Fritz Waitz, seen in the figure above) allowed the classifer to click through the PHIPS images while the program organized the classified particles for them.

- Chain aggregates were defined by:
  - 3 or more particles oriented in a linear fashion and/or...
  - Multiple particles joined by small joints and/or…
  - Elongated
- Confidence was determined by the classifier:
  - Lowest Confidence (1): One of the three definitions observed.
  - Moderate Confidence (2): Two of the three definitions observed.
  - Highest Confidence (3): All three definitions observed.



(Click GIF image to enlarge)

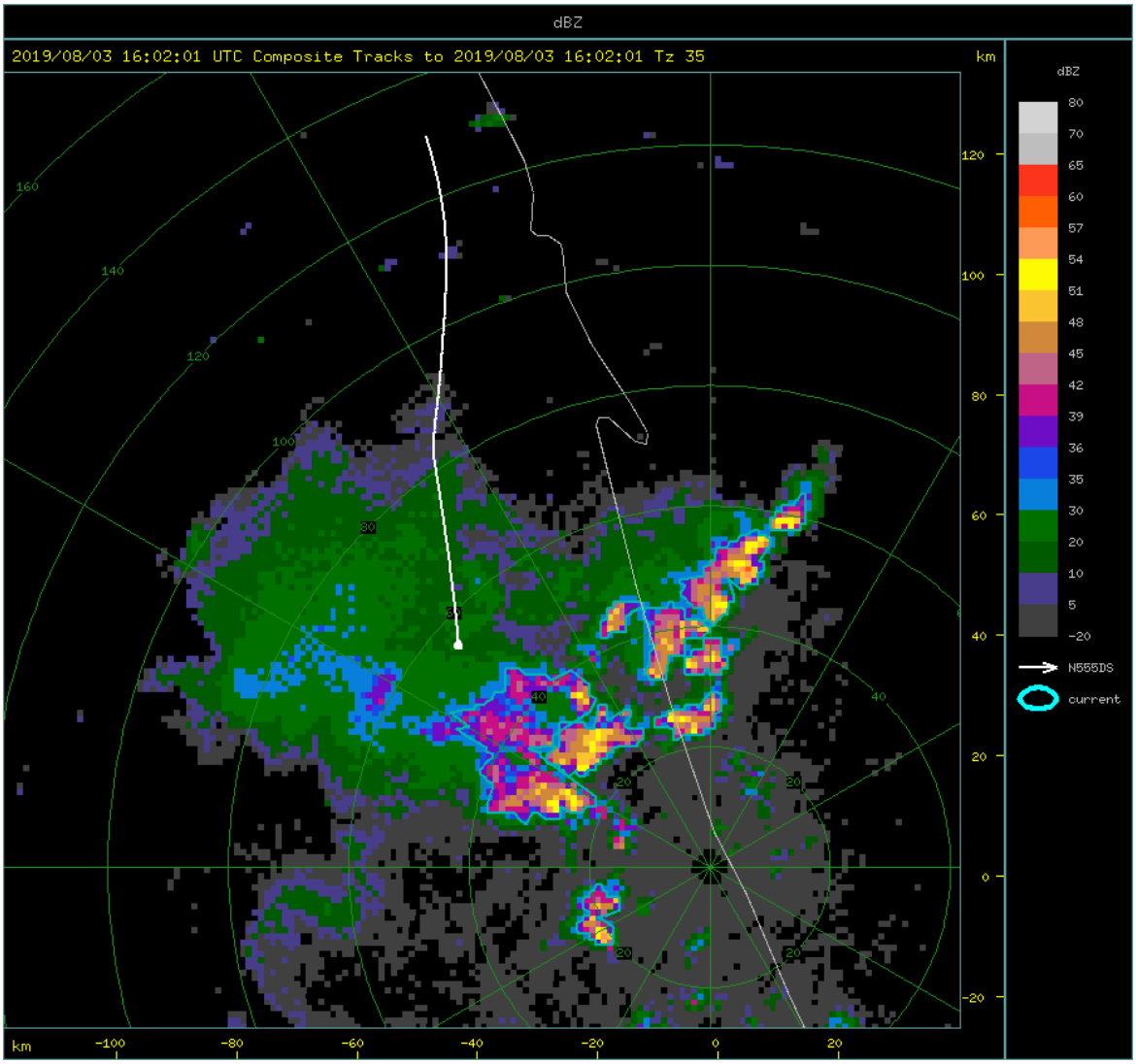
TITAN-Rview Radar Animation (figure above) using data from the NWS KMLB WSR-88D. Aircraft track is depicted as the white line where the slightly apparent buldge in the line is the current aircraft postion with the line being 5 minutes of past flight track with repect to the time stamp. Blue circles represent the TITAN storm tracking algorithm (35 dBZ threshold).



3.) Using flight-leg intervals (where the aircraft was level at a constant altitude) shown in the figure above, calculate the amount of the chain aggregates per flight-leg, location (distance from storm core), and compare to in-situ environmental conditions.

RESULTS

First Flight Leg: 15:50:00 - 16:01:00 UTC



(Click image to enlarge)

Rview image (figure above) depiciting NEXRAD KMLB WSR-88D Level II composite reflectivity (dBZ) as well as aircraft flight track data (white line) and TITAN storm tracking data (blue outlines - 35 dBZ threshold [Tz]). White aircraft line showing 11 minutes of previous aircraft track. White bulge at the bottom point of the white line is the aircraft's position at 16:01:00 UTC.

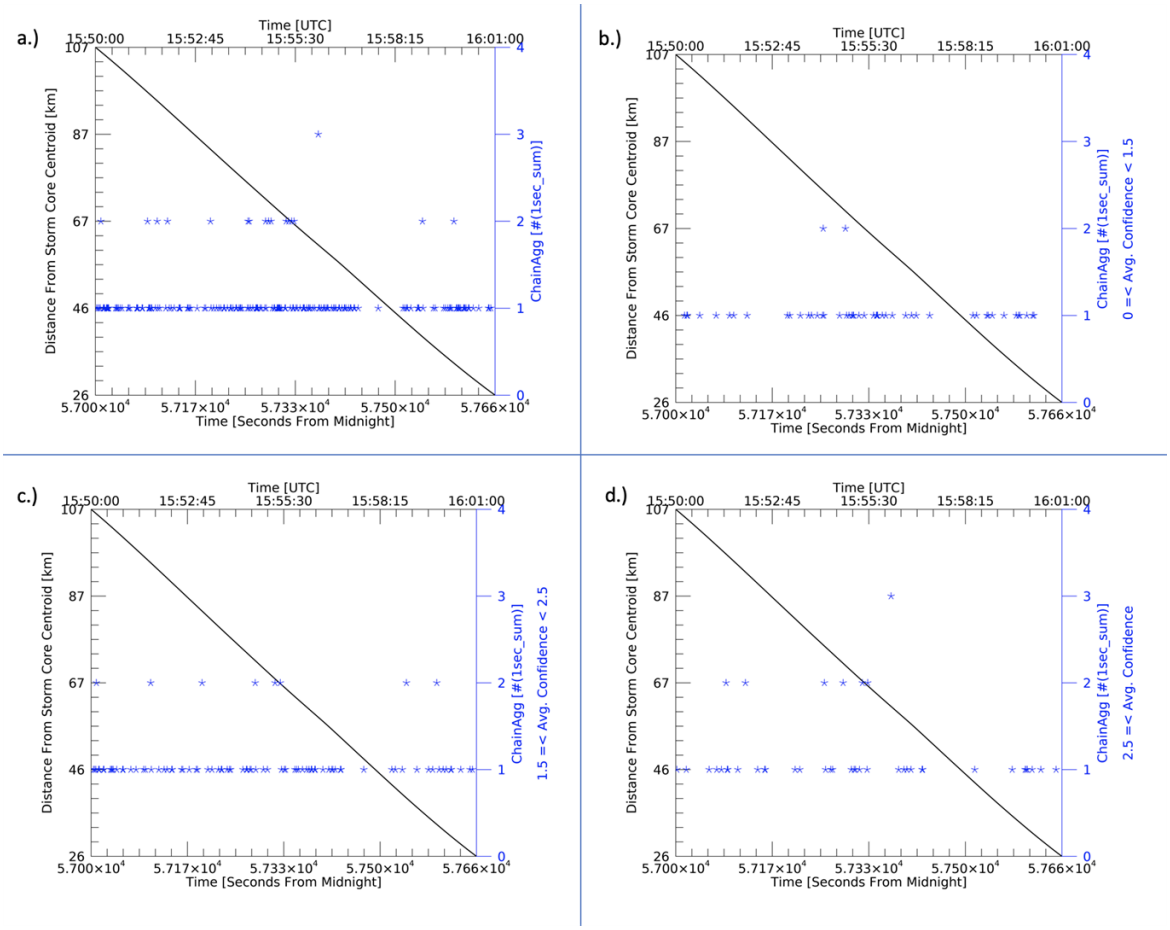


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Figure above showing total amount of chain aggregates in flight leg 1 (a), while (b-d) show chain aggregates in varying average confidence intervals.

- (a) Total Chain Aggregates = 198
- (b) 0 ≤ Avg. Confidence < 1.5 = 52
- (c) 1.5 ≤ Avg. Confidence < 2.5 = 96
- (d) 2.5 ≤ Avg. Confidence = 50

PHIPS Images

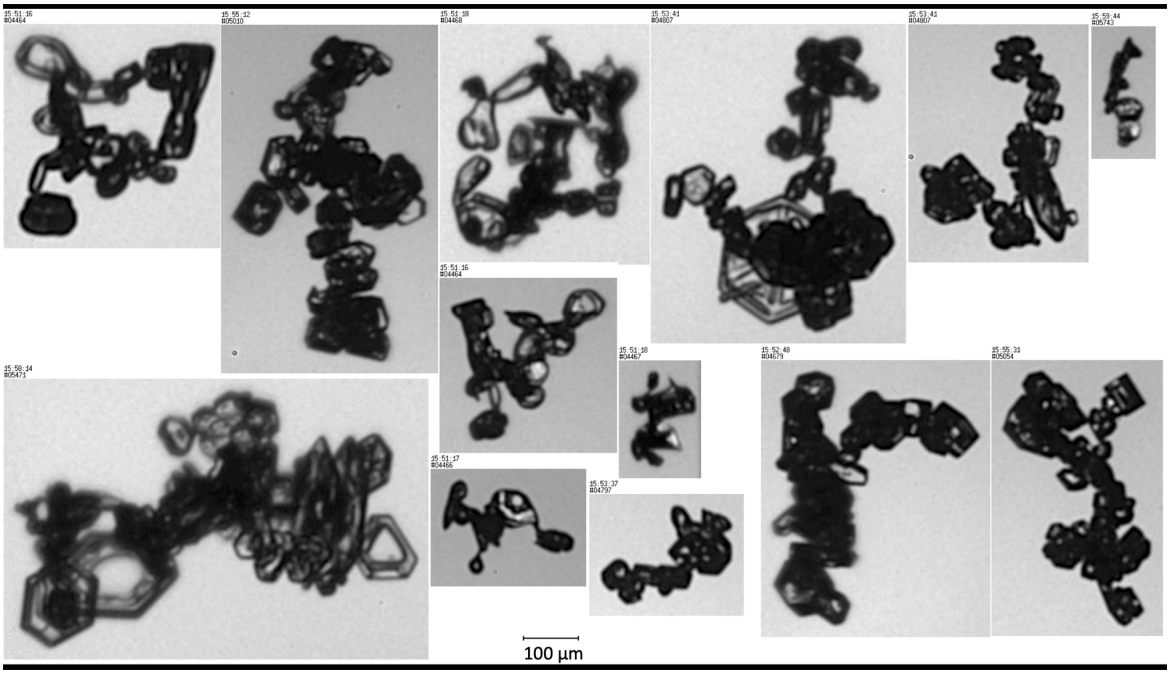

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Figure above showing a few particles images taken by the PHIPS probe during the first flight leg.

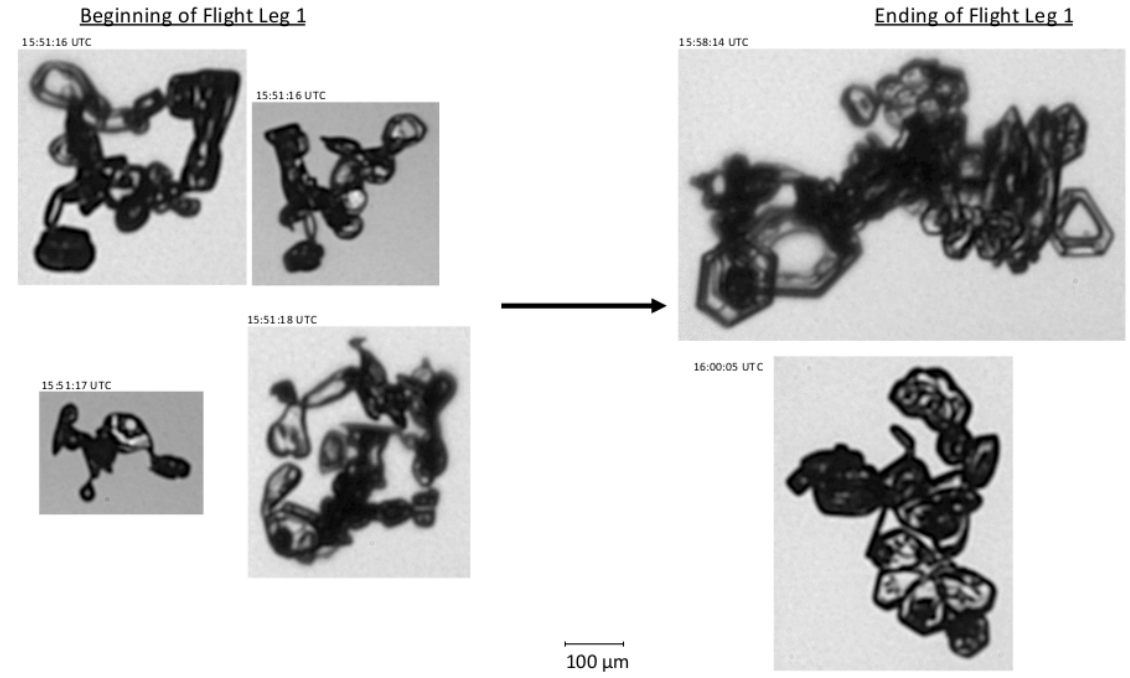

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Figure above showing a few particles images taken in the early stage verses the later stage of the first flight leg.

All Flight Legs Summary

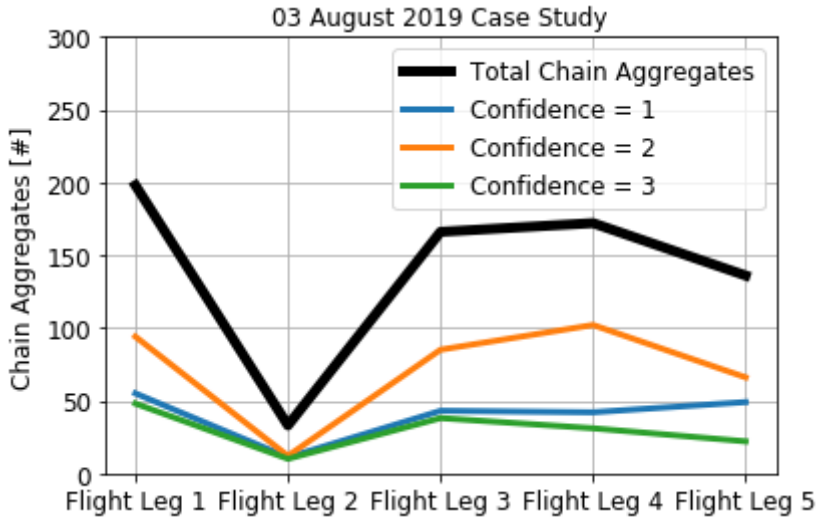
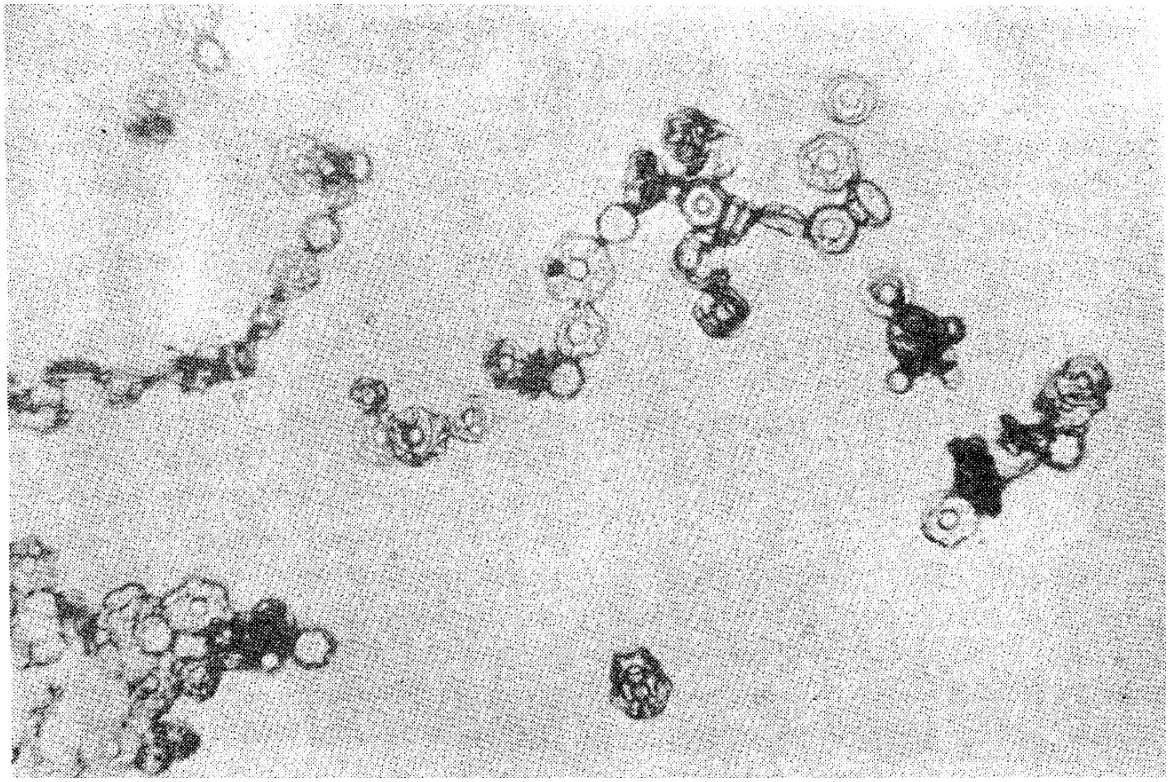


Figure above showing the amount of chain aggregates for all the flight leg segments from the 2019/08/03 flight. Colored lines show the different confidence levels, while the black line shows the total chain aggregates observed.

FUTURE WORK

- Compare locations of chain aggregates verses electric fields observed during sampling.
  - Literature suggest high crystal concentrations and E-fields necessary for chain aggregates[4,5].



[4]Saunders & Wahab (1975) laboratory image.

- Compare results from this case study to other flights during the CapeEx19 field campaign.
- Origin of chain aggregates are still unknown.
  - Additional aircraft flights through and around the vicinity of the storm core may provide further insight.
- More microphysical analyzation of chain aggregates needed before implementation into cloud microphysical aggregation models.

ACKNOWLEDGMENTS

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AUTHOR INFORMATION

CHRISTIAN NAIRY

Grand Forks, ND 58201 – (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

Graduate, Atmospheric Science M.S.

University of North Dakota – John D. Odegard School of Aerospace Sciences

Expected Graduation Date: August 2021

ABSTRACT

Multiple aircraft field projects have obtained in-situ observations of chain-like aggregates of crystals in cirrus clouds of tropical thunderstorms. Observations of these chain aggregates date back to 2002 when the 2D-C cloud imaging probe sampled the cloud tops of convection produced over the Amazon Rainforest. More recently, these chain aggregates were observed during research flights of the North Dakota Citation Research Aircraft over Florida in 2015 and 2019 (CAPE2015 & CapeEx19). In 2019, the airborne Particle Habit Imaging and Polar Scattering (PHIPS) probe obtained higher resolution stereographic images and angular light scattering functions of individual ice particles. With over 170,000 PHIPS images available from the field project, manually classifying images to determine locations of the chain aggregates is time consuming. The aircraft's position in conjunction with concurrent, multi-radar observations are utilized to determine if chain aggregates occur more often adjacent to the convective cores or at different altitudes within the cirrus cloud anvil. An analysis of the CapeEx19 flight on August 3, 2019 showed that of a total of 17,146 PHIPS images, 7,151 where classified as chain aggregates. Since these chain aggregates can contain multiple plates and columns connected by small joints, these chains are sufficiently larger than individual 100-300 μm diameter plates themselves. Determining the process which generate these large chain aggregates in cirrus cloud anvils should enable models to predict their occurrence.

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