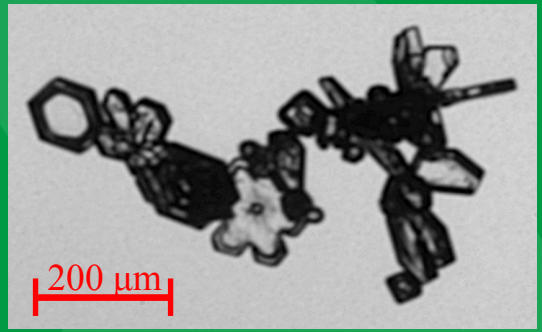
UNIVERSITY OF NORTH DAKOTA

Chain Aggregates Observations during Recent Field Campaigns

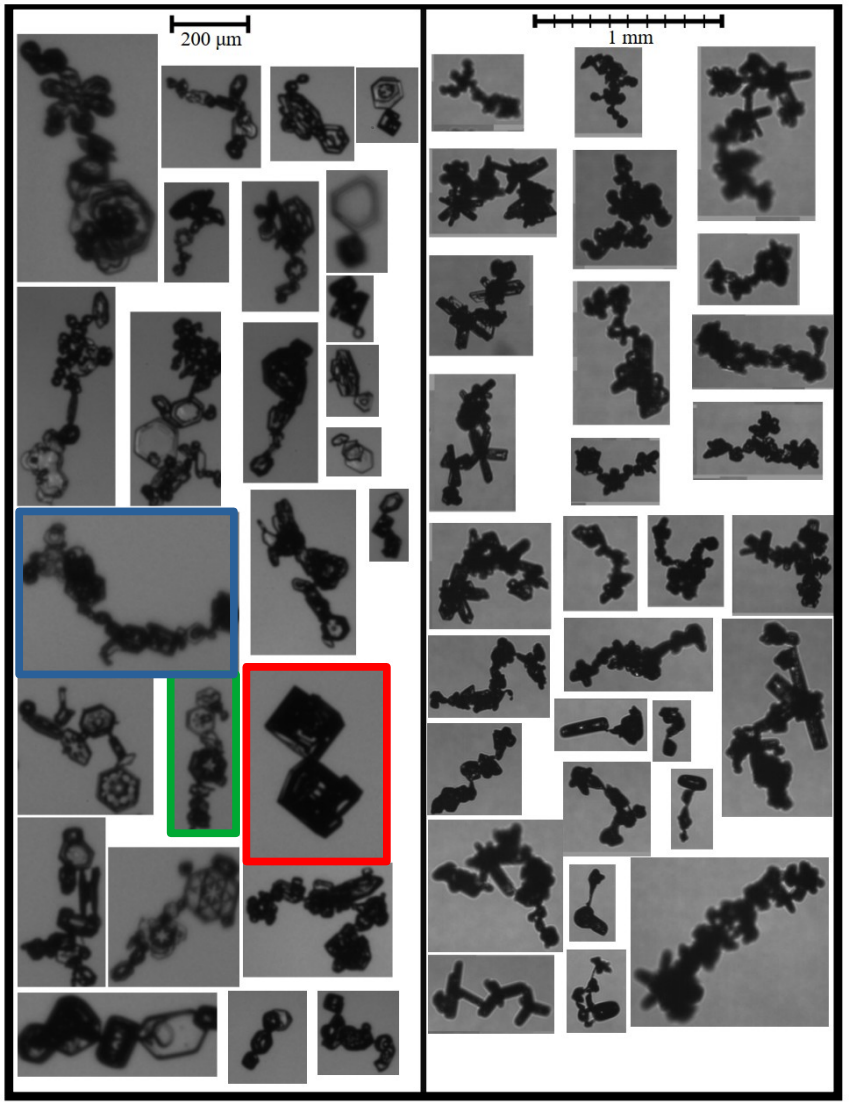


David Delene, Christian Nairy, Marwa Majdi, Andrew Detwiler, Shawn Wagner, and Youngsuk Oh

Busan IAMAS-IACS-IAPSO Joint Assembly 2025 (BACO-25), M04, C101-C102, July 22/23 - Cloud-Precipitation-Aerosol Studies Symposium, 14:45-1500 Tuesday 22 July 2025 in Convention Hall 1F, C101 – 102, Busan, Republic of Korea

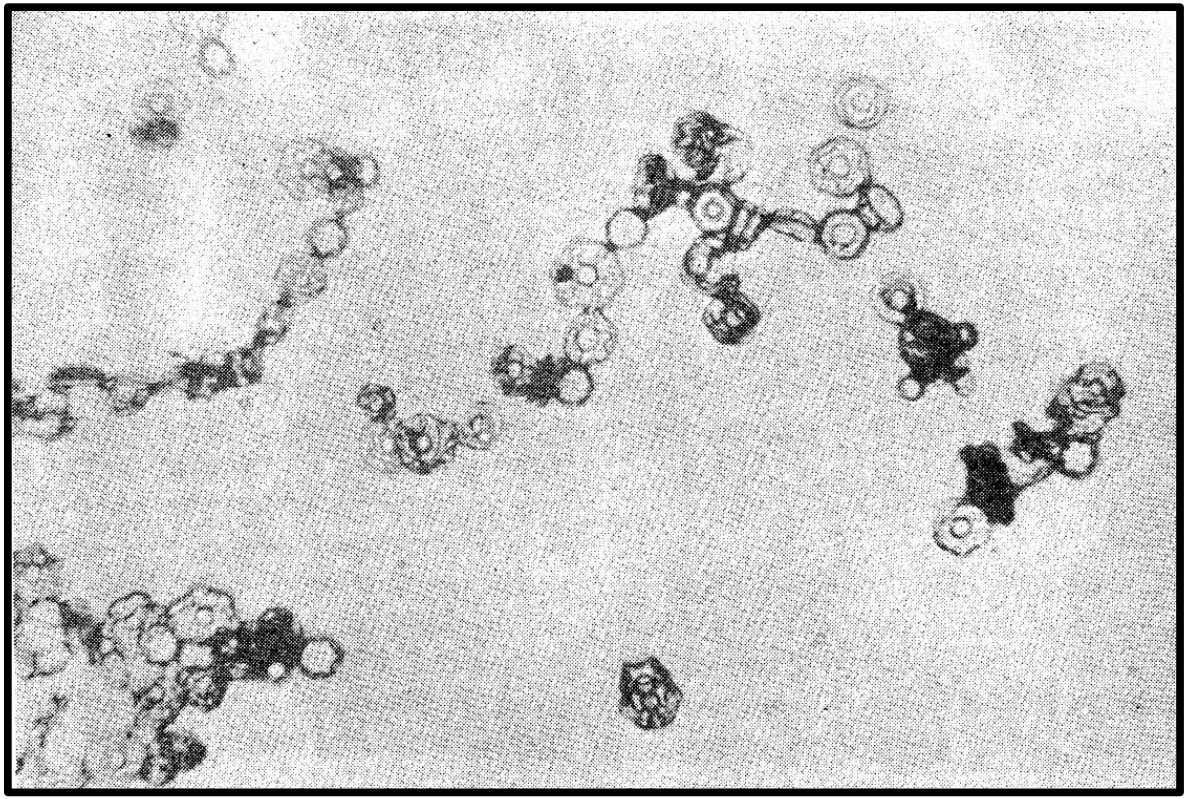
Motivation for Research

- Cloud aggregation is a fundamental process important for precipitation.
- Chain aggregates are long, linear aggregates that are made of similar sized monomers crystals.
- Not well understood.
  - Where and How? Importance of electrical forces?
    - Inconsistencies exists between cloud chamber experiments and aircraft observations.



Laboratory Observations of Chain Aggregates

- In High Electric Fields
- Ice Crystal Concentrations Between 3 and 4 x 10^{6} m^{-3}
- Chain aggregation seems to require a minimum field.
  - 60 kV m^{-1}
- Chain aggregation found to be temperature dependent.
  - Maximum efficiency found at ~ -8 °C



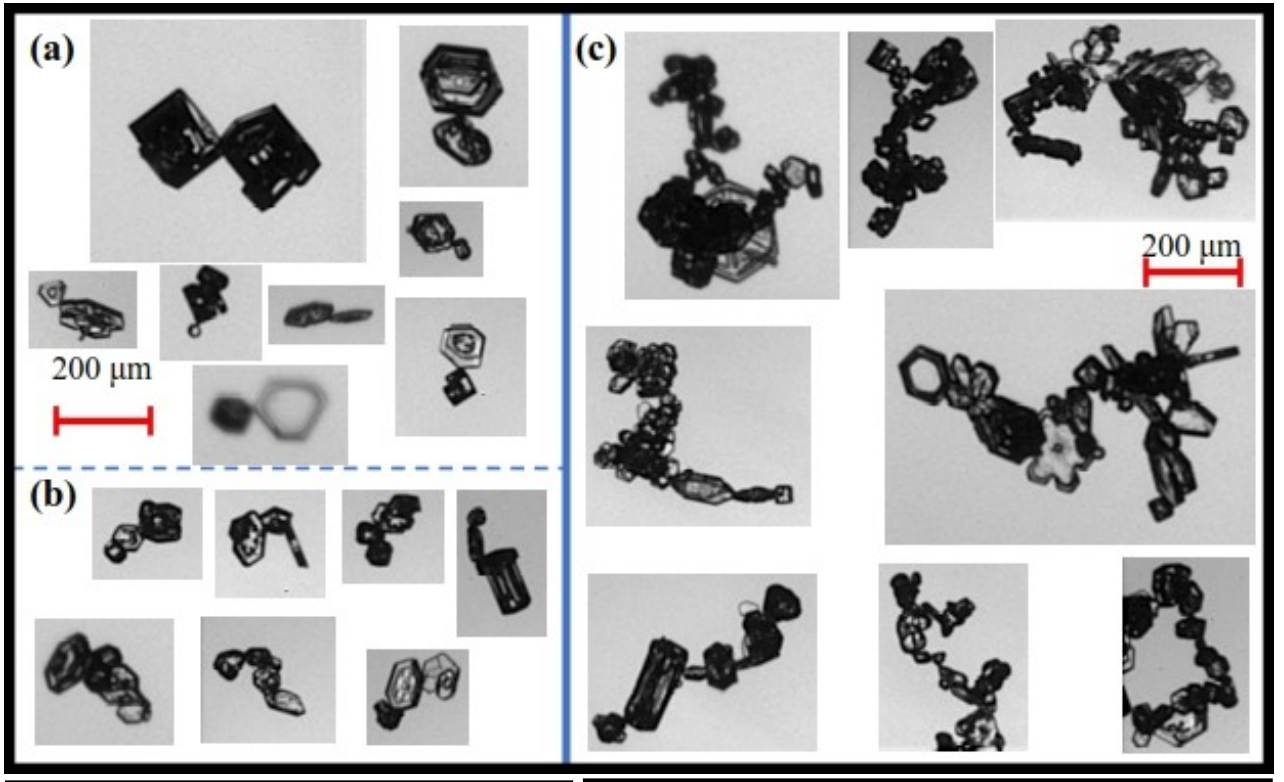
Chain Aggregates on form var slides that were generated in a cloud chamber. Adapted from Saunders and Wahab, 1975.

Observational Research Objectives

- Understand the context of where and when chain aggregates are observed in terms of the time evolution of cloud systems to provide information related to possible formation processes.
  - Machine Learning methods are a critical tool for identifying the millions of aggregate images obtained during a single research flight.
- Place chain aggregate observations into context with other measurements and relate them to the storm's life cycle.

Aircraft Observations of Chain Aggregates

- PHIPS images of chain aggregates (a and b) comprised of ice crystals found in Florida cirrus anvil clouds produced by summertime convection observed during the CapeEx19 field campaign.
- CPI images of chain aggregates (c) found near convective band associated with wintertime convection off the New England coast.



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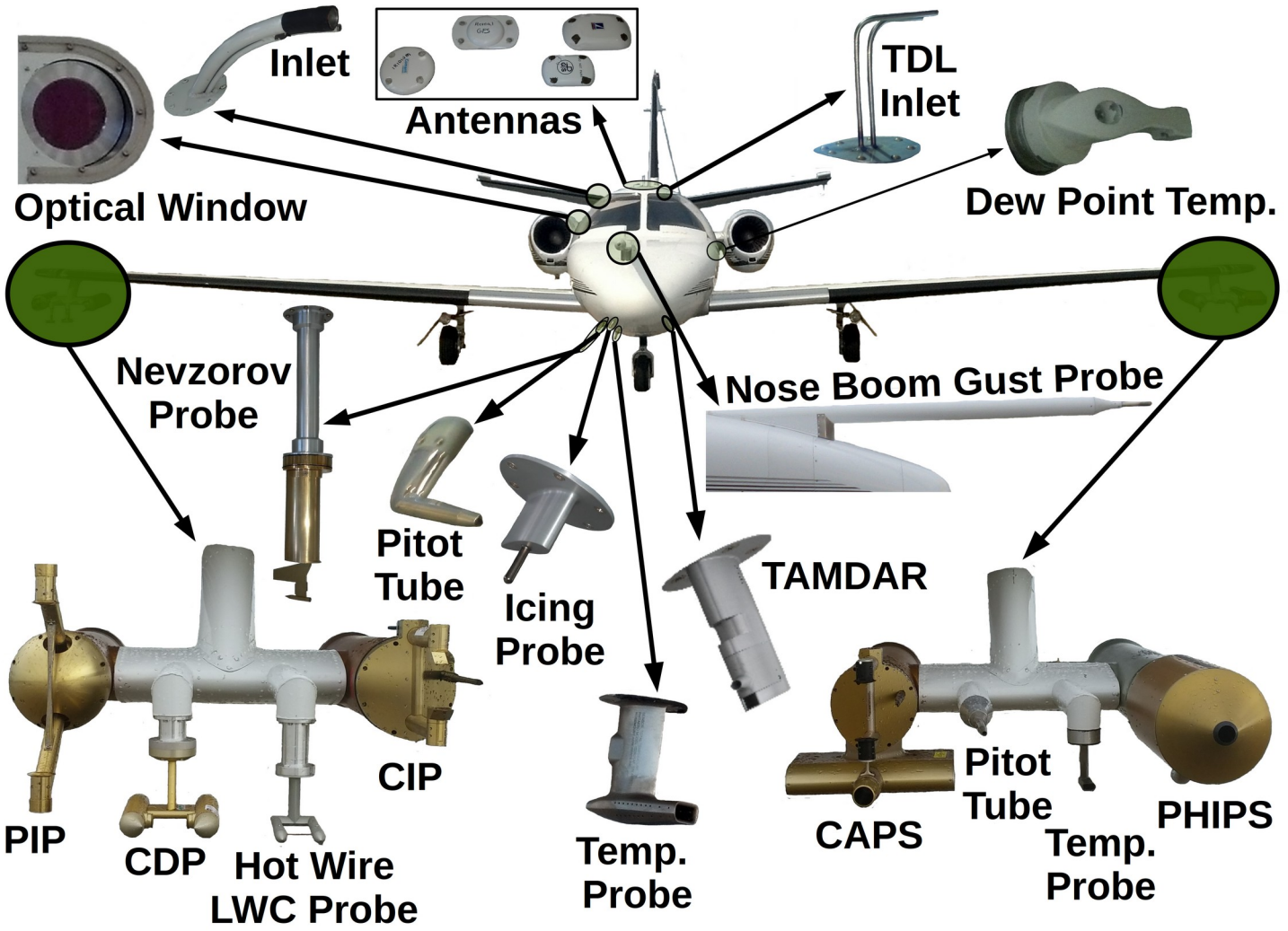
Nairy, Christian M., David J. Delene, Joseph A. Finlon, John E. Yorks, Emma Järvinen, Martin Schnaiter, Andrew J. Heymsfield, Andrew G. Detwiler, Lynn A. McMurdie, Unveiling In-situ Observations of Ice Crystal Chain Aggregates in Winter Storms. Journal of Geophysical Research Letter, In Review, 2025`

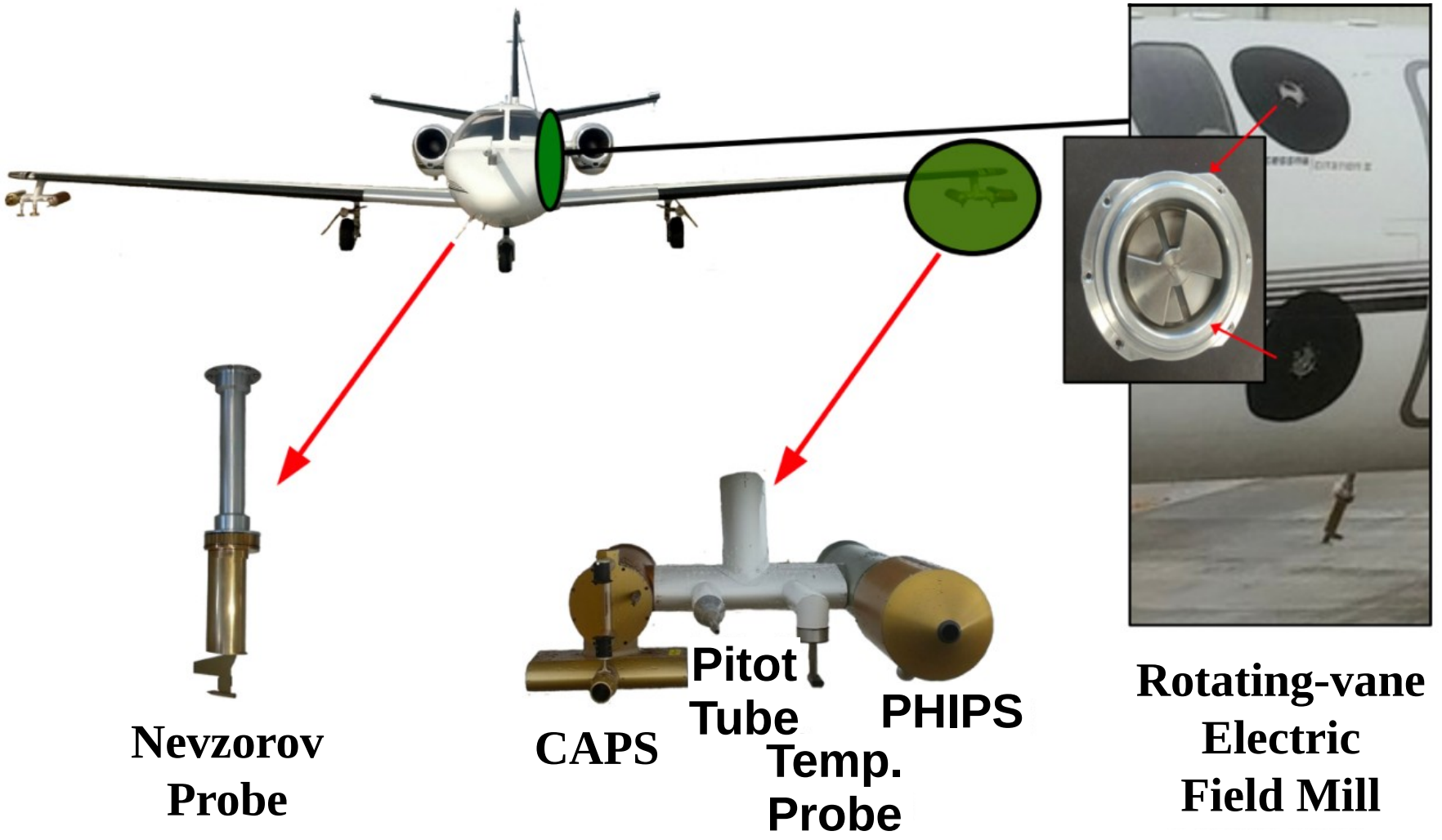
CapeEx19 Dataset and Instrumentation

12 Flights

2019/7/22
2019/7/24
2019/7/25
2019/7/26
2019/7/29
2019/7/30
2019/7/31
2019/8/01
2019/8/2a
2019/8/2b
2019/8/3a
2019/8/3b

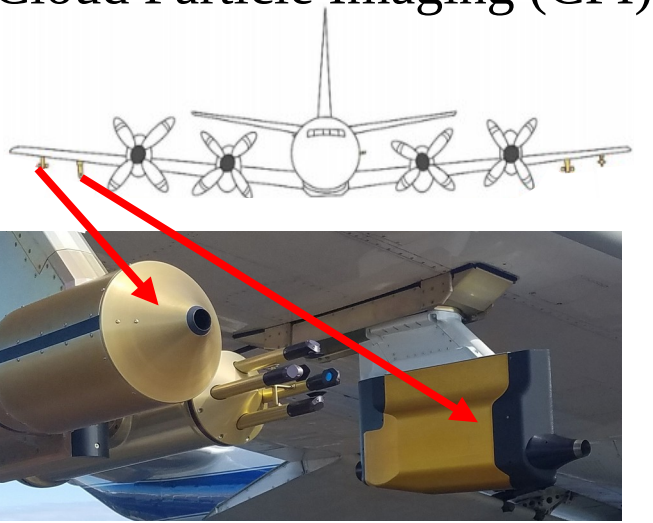


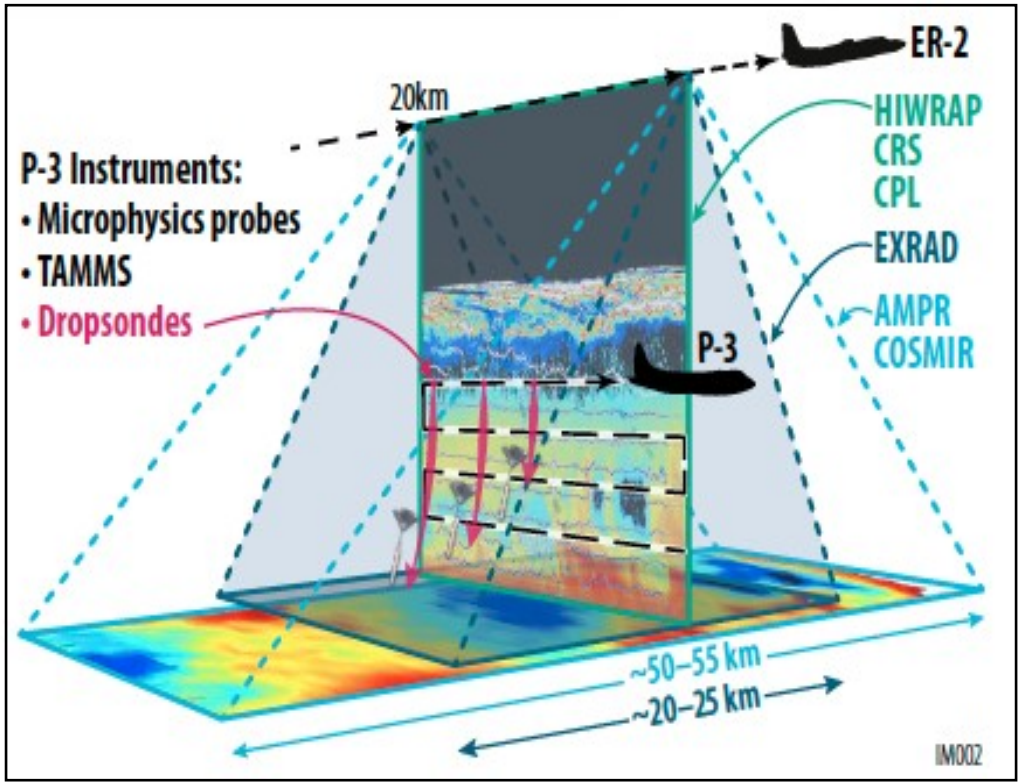
CapeEx19 Unique Measurements



IMPACTS Field Project and Instrumentation

- **I**nvestigation of **M**icrophysics and **P**recipitation for **A**tlantic **C**oast-**T**hreatening **S**nowstorms (IMPACTS).
- NASA P-3 Orion Research Aircraft
  - Particle Habit Imaging and Polar Scattering probe (PHIPS)
  - Hawkeye-Cloud Particle Imaging (CPI)



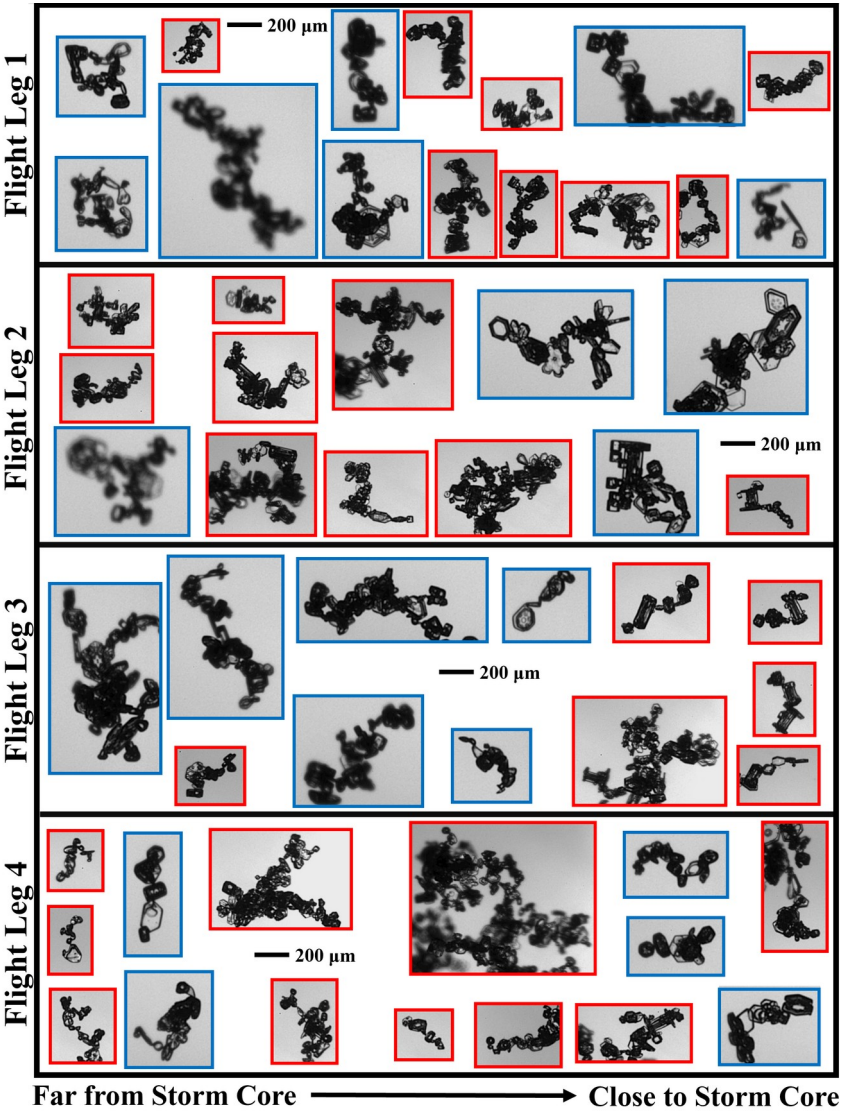


Adapted from the NASA IMPACTS executive summary (https://espo.nasa.gov/impacts/).

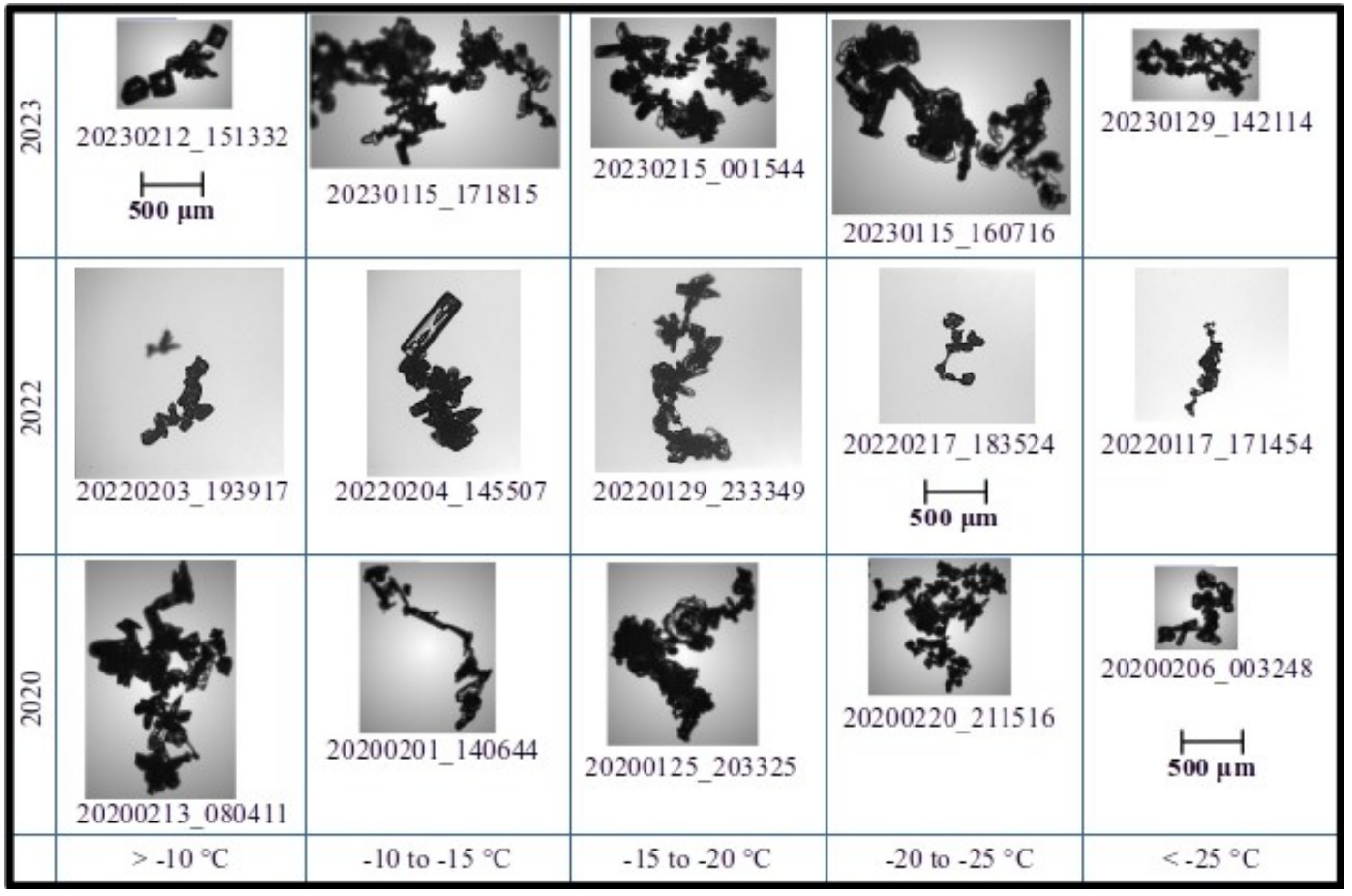
CapeEx19
Chain Aggregates

- Illustration showing representative chain aggregate images observed during the CapeEx19 field campaign grouped by Flight Leg obtained while sampling anvil cirrus clouds.

- The flight legs are at 10 km AGL from 2019/08/03a research flight, and images are group from far way from the convective storm core to close to the convective storm core.



IMPACTS Representative Chain Aggregates

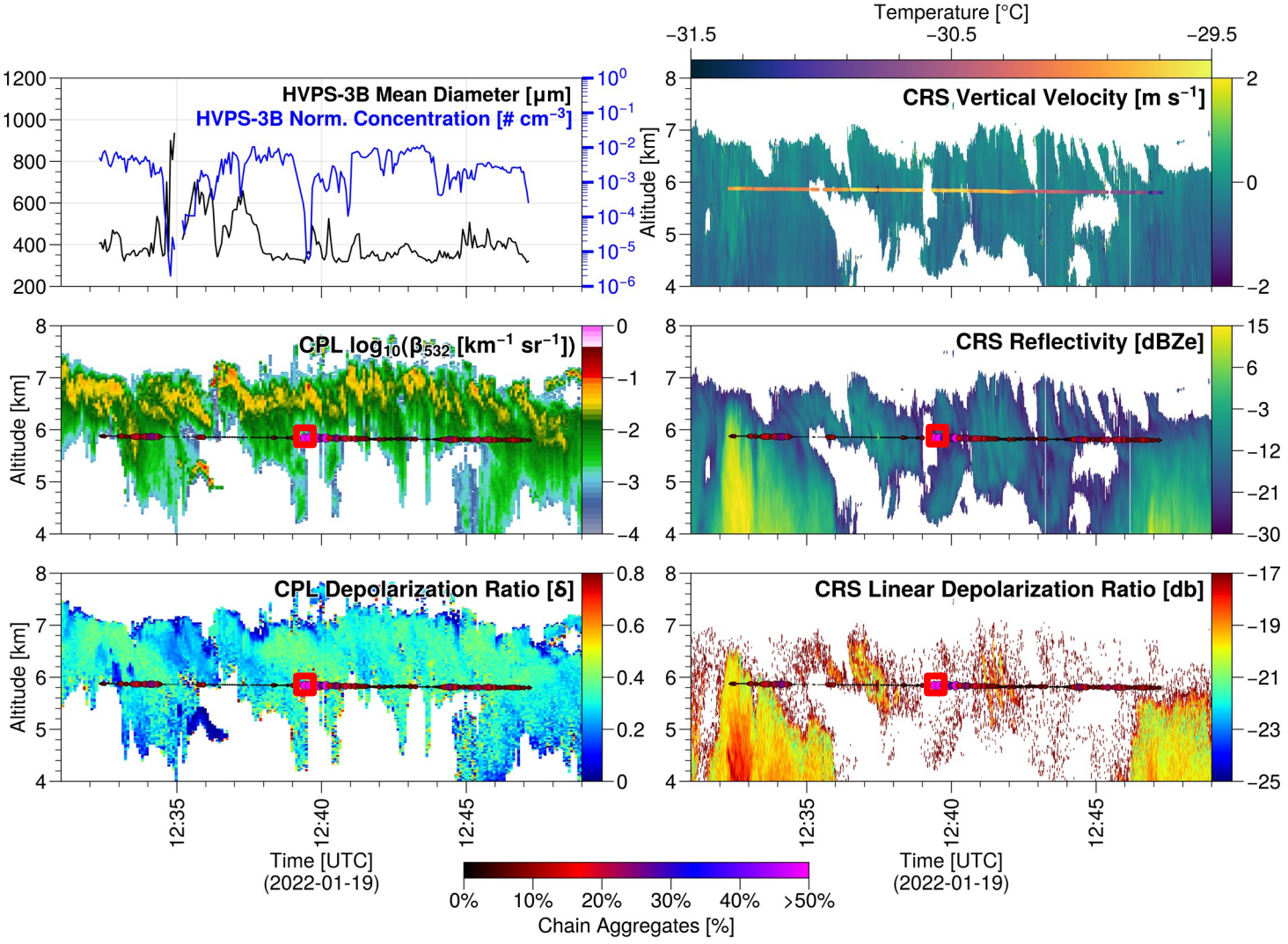


Representative chain aggregate images observed during IMPACTS grouped by temperature and deployment year.

Contextualization of Chain Aggregate Observations

The collocated in-situ and remote sensing observations obtained by the NASA P-3 and ER-2 on 19 January 2022.

The Red Box highlights an area of high chain aggregates percentage.



Crystal Habit Classifications

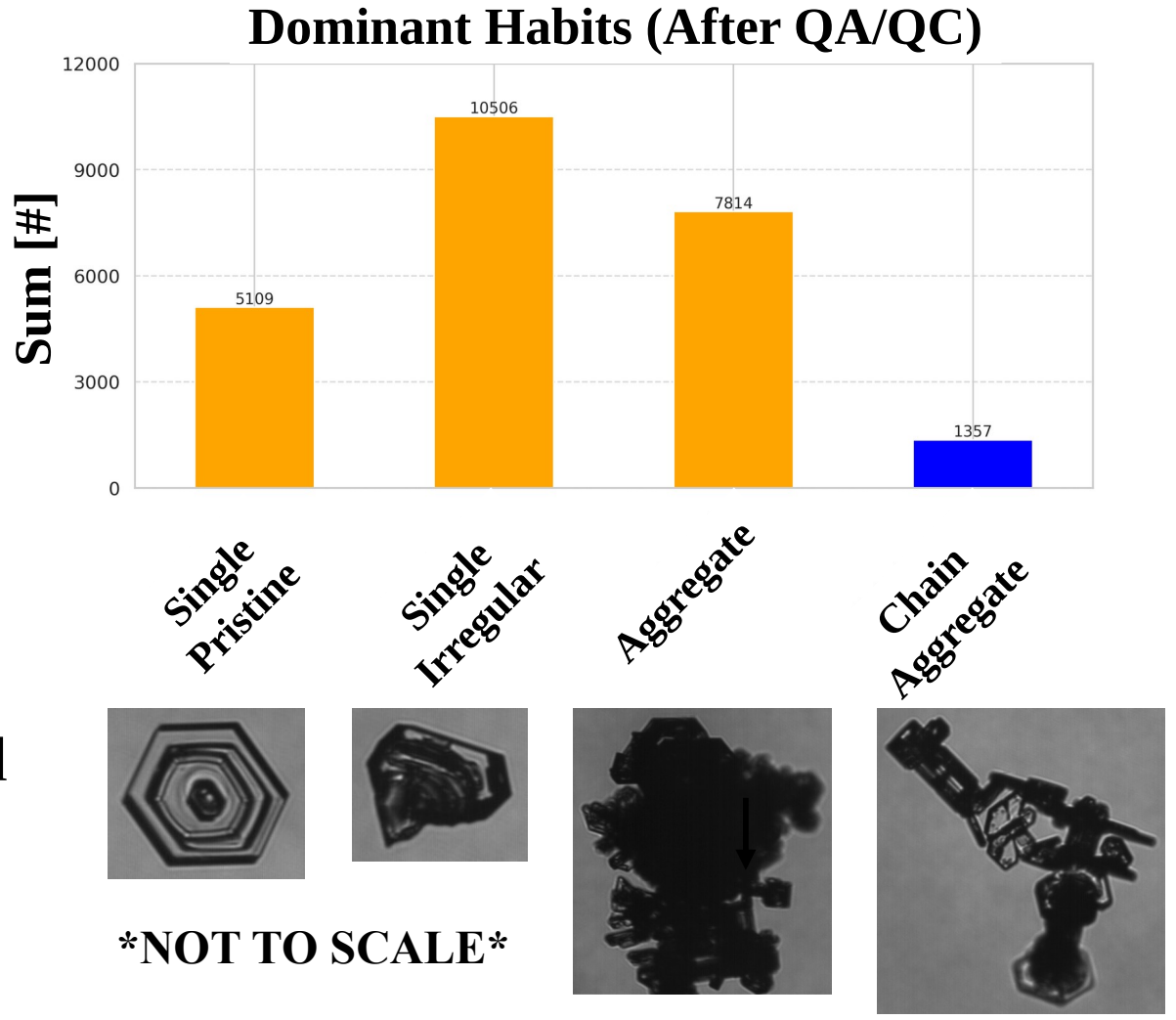
- 5 Flight Segments Classified:
  - *Total Time Coverage:*

    1hr 40m 49s
  - *Temperature Range:*

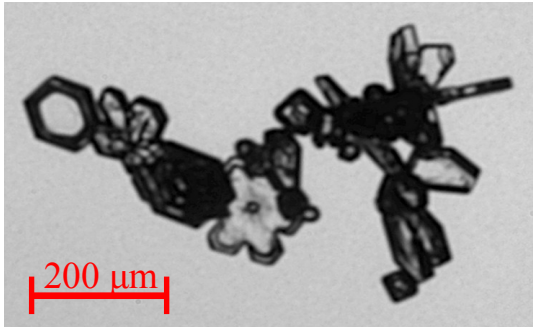
    -36 to -5 ºC
- Total # of Particles Classified (after QA/QC):

  24,786
- # of Chain Aggregates Classified (after QA/QC):

  1,357



Conclusions



- First high-resolution observations of ice crystal chain aggregates in winter storms.

- Chain aggregates observed in winter storms show similar characteristics to chain aggregates observed in upper-level clouds associated with summertime convective storms.

- Formation process are uncertain, which can be improved with the localization of chain aggregates in relationship to in-cloud electric field and remote sensing measurements.

Publications, References, and Acknowledgments

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Nairy, Christian, David J. Delene, Joseph Finlon, John E. Yorks, K. Lee Thornhill, Applying and Evaluating Random Forest Classification to Identify Ice Crystal Chain Aggregates During the IMPACTS Field Campaign, Talk presentation given on Wednesday 15 January 2025 at 8:45-9:00 AM in Room 224 at American Meteorological Society's Second Symposium on Cloud Physics at the 105th AMS Annual Meeting, from January 12 - 16, 2025 in New Orleans, LA.

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Forth Coming Publications

Nairy, C. M., D. J. Delene, A. G. Detwiler, J. M. Schmidt, P. R. Harasti, M. Schnaiter, E. Järvinen, T. D. Walker, Ice Crystal Chain Aggregates in Florida Cirrus Cloud Anvils - 3 August 2019 Case Study. Journal of Geophysical Research: Atmospheres. In Review, 2025.

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Future Work (NASA Grant 80NSSC25K7971)

- Apply Machine Learning (XGBoost, Random Forest, Convolutional Neural Network) across all research flights conducted during the IMPACTS field campaign.
- Contextualize chain aggregates within storm life-cycles for improved understanding in the chain aggregation process.