Quantifying Electrical Influences on Ice Crystal Aggregation

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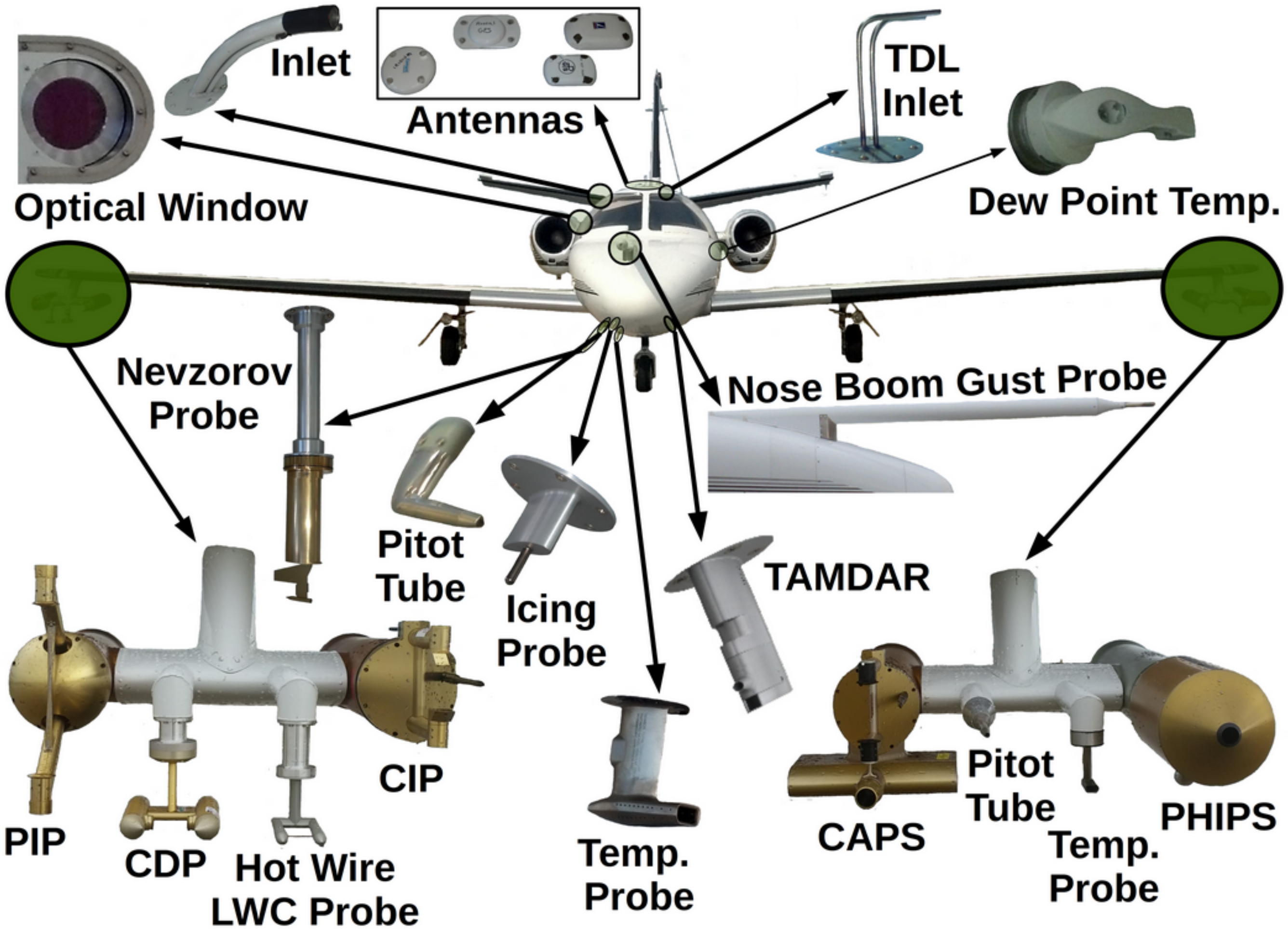
Project Objective

Qualtify the role of electric fields in ice crystal chain aggregation under realistic cloud conditions using the controlled environment of a cloud chamber.

NIMS Cloud Chamber
Expansion Types, Volume 29.3 m^3

Field Project Observations: CapeEx19 and IMPACTS



<u>High Resolution Probes:</u>

- Cloud Particle Imager (CPI)
- Particle Habit Imaging and Polar Scattering (PHIPS)

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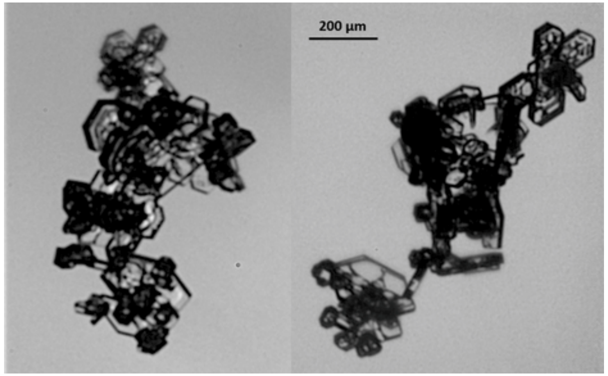
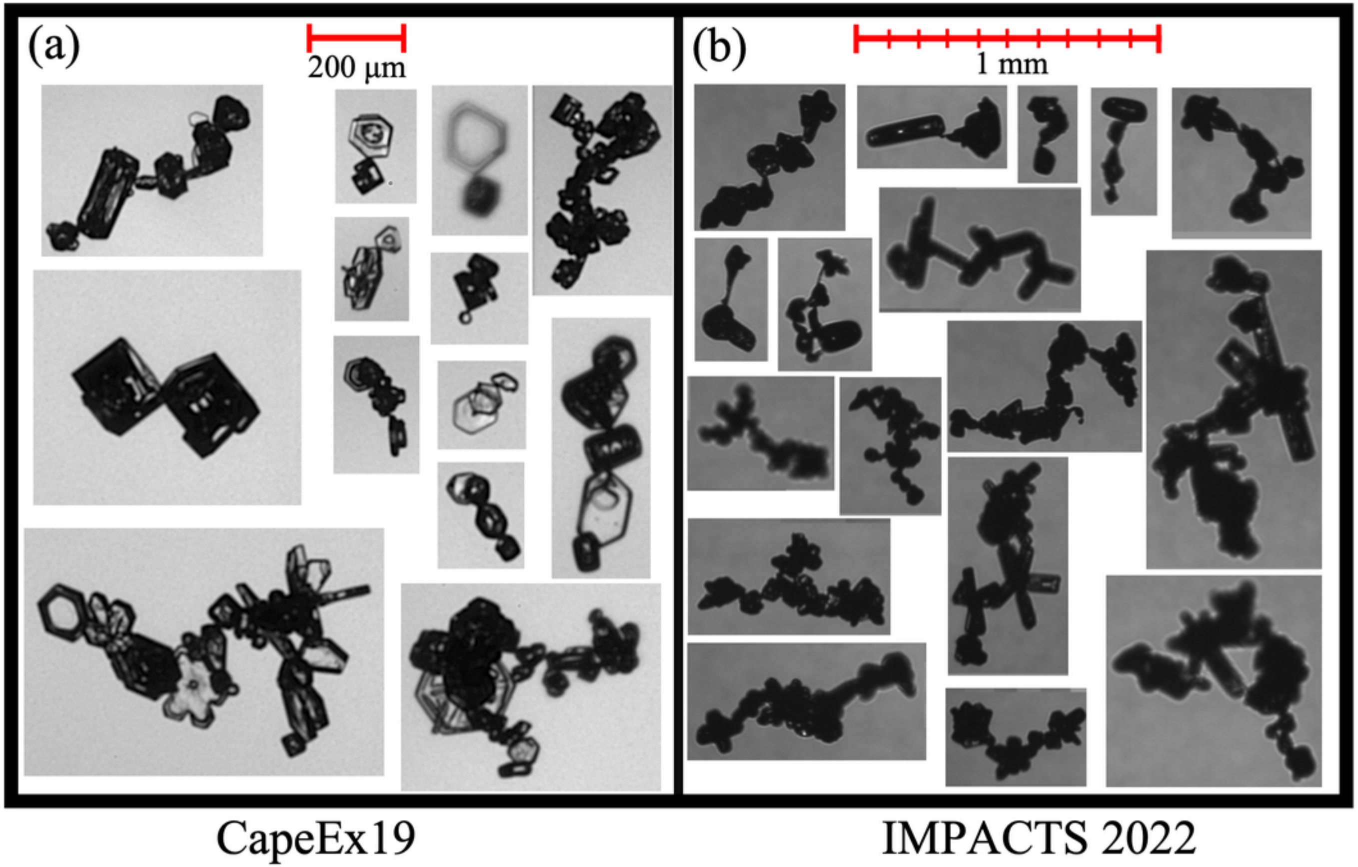


Stereo image pairs of chain aggregates obtained within Cirrus cloud anvils over Florida.

Observations: Chain Aggregates

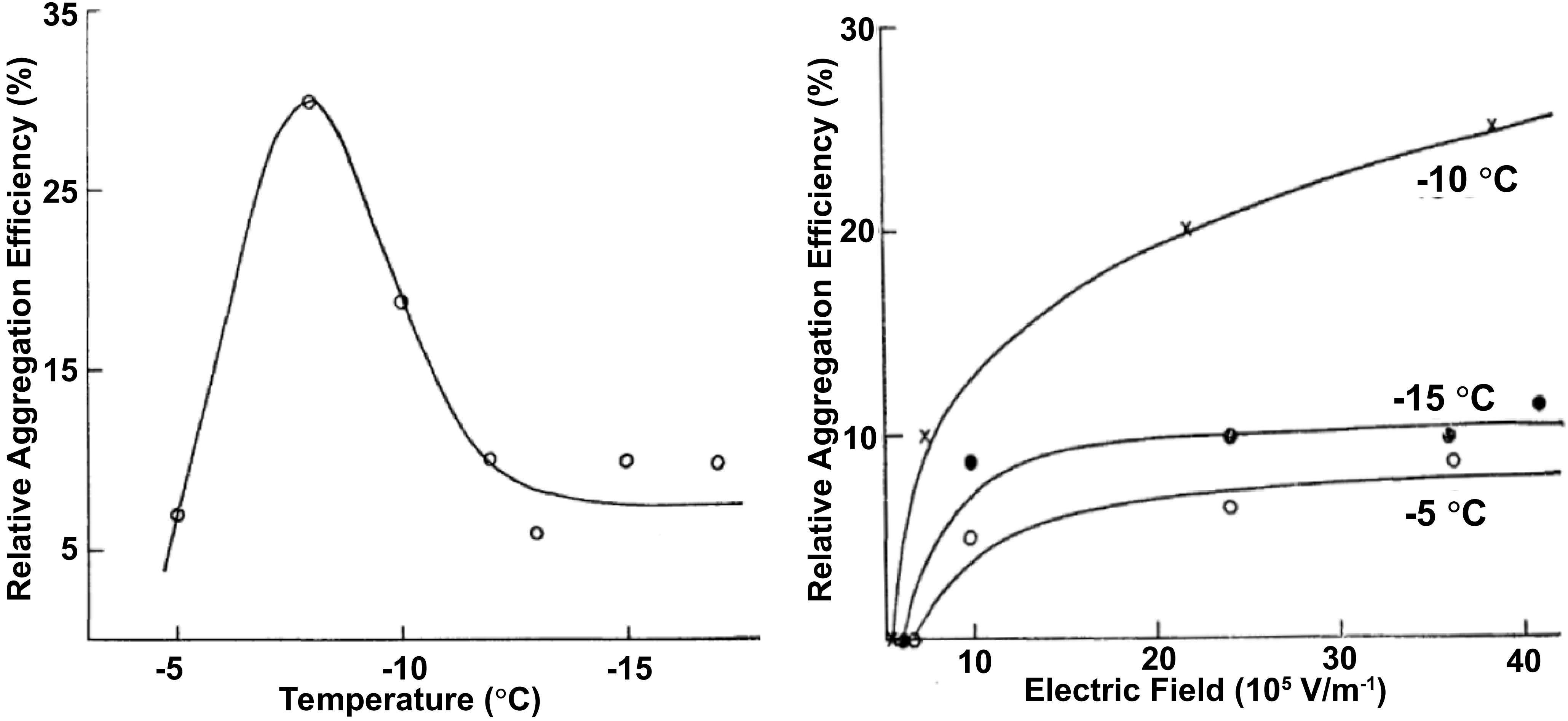


Collage of chain aggregates (a) imaged by the Particle Habit Imaging and Polar Scattering (PHIPS) probe during the Cape Canaveral Experiment in 2019 (CapeEx19) and (b) imaged by the Hawkeye-Cloud Particle Imaging (CPI) probe during the Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS) field campaign in 2022. Emma Järvinen and Martin Schnaiter provide PHIPS images.

Primary Goal: Aggregation Efficiencies

Measure ice crystal chain aggregation and aggregation efficiencies under varying electric field strengths in realistic atmospheric cloud conditions using advanced, state-of-the-art instrumentation.

- Use cloud chamber experiments to determine the efficiency of chain aggregate production under a range of electric fields and temperatures. Cloud probes are used to assess the change in aggregation efficiency with electric field strength at a range of temperatures.
- Compare the statistical distribution of chain aggregate parameters derived from images produced in the cloud chamber experiments with in-situ observations from recent field campaigns to determine how realistic are the produced chains.



Adapted from Saunders and Wahab (1975). Left anel shows the relative aggregation efficiency as a function of temperature for an electric field of 200 kV m^{-1}, ice crystal concentration of 3-4 x 10^6 m^{-3} and size ~50 μm in diameter. Right panel shows the relative aggregation efficiency as a function of electric field for three values of temperature using the same ice crystal concentrations and ice sizes as panel (a).

Methodology: Chamber Setup

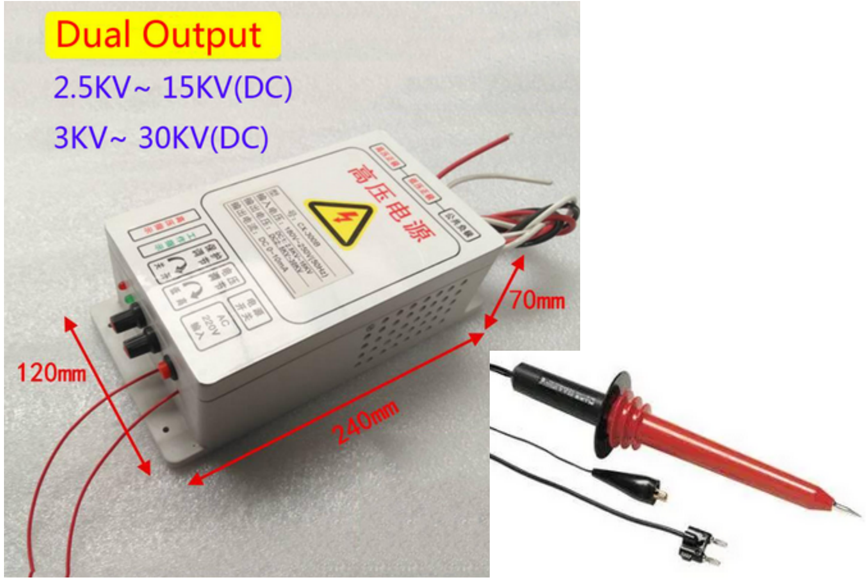
Schematic showing the Aggregation Enclosure within the cloud chamber. Ice crystals are generated using pressure drops at a constant rate to create a supersaturated environment. A “Aggregation Enclosure” is placed inside the cloud chamber. The Sample Area is where the cloud probe measures the ice crystals.

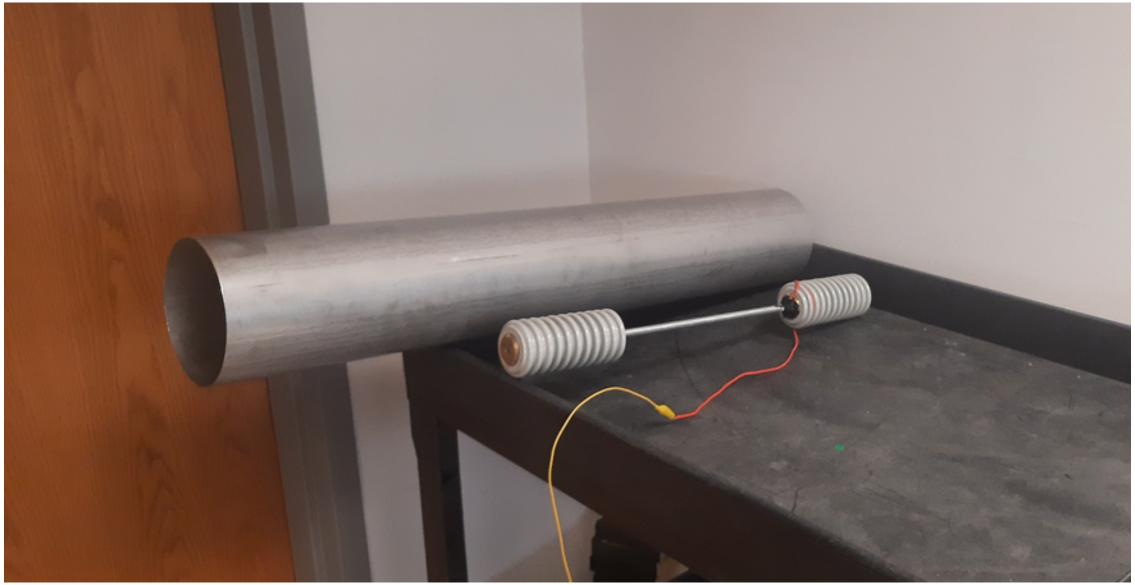
Aggregation Enclosure

- A high-voltage power supply is used to generate a horizontal electric field that can affect ice crystals falling under gravity.
- An electric field potential difference is created between the central high-voltage electrode and surrounding Grounded Metal Cylinder to produce electric fields up to 1.2×10^5 V m^{-1}.
- The stainless steel rod is coated with a Fluoro Silane compound (1H,1H,2H,2H-Perfluorooctyltriethoxysilane) to create a hydrophobic (water-resistant) surface.
  - Nanometer-thin insulating layer that does not materially alter the electrode geometry.

Aggregation Enclosure

- The rod is connected to a high-voltage (up to 30,000 volts) power supply located outside the chamber.
- An outer conductive cylinder is grounded and serves as the outer electrode (radius $r_2 \approx 0.10\text{–}0.12$ m, smooth, thin-wall (0.065 in) metal cylinder).





Electric Field Environment

- The coaxial configuration ensures a symmetric and well-defined field within the Aggregation Enclosure
- The electric field within this geometry is governed by the classical solution for coaxial cylindrical conductors.

$$E(r) = \frac{V}{r \cdot \ln \frac{r_2}{r_1}}$$

E(r) is the electric field at a distance *r* from the axis
V is the applied voltage
r_1 is the radius of the inner rod
r_2 is the inner radius of the outer conductive cylinder.

- The maximum field strength occurs at the surface of the inner electrode.
- The equation remains valid with the fluorosilane coating as it’s effects on electric field geometry is negligible

Cloud Chamber Cycle Run

- **Control Experiment:** The aggregation efficiency is measured with no electric field applied at a fixed temperature to provide a baseline reference.
- **Electric Field Variation:** At each fixed temperature of the Control Experiment, electric field strength is varied to determine its influence on aggregation efficiency.
- **Temperature Variation:** Conduct runs at specific temperatures of -8, -15, -22 and -2 °C

Thank You – Questions and Discussion

https://atmoswiki.azurewebsites.net/doku.php?id=atmos:citation:instruments:cloudchamber-chainag:home

Related Publications

Schmidt, Jerome M., Piotr J. Flatau, Paul R. Harasti, Robert D. Yates, David J. Delene, Nicholas J. Gapp, William J. Kohri, Jerome R. Vetter, Jason E. Nachamkin, Mark G. Parent, Joshua D. Hoover, Mark J. Anderson, Seth Green, and James E. Bennett, Radar Detection of Individual Raindrops, Bulletin of the American Meteorological Society, 100, 2433-2450, 2019, https://doi.org/10.1175/BAMS-D-18-0130.1.

Wagner, S. W. and Delene, D. J., Technique for comparison of backscatter coefficients derived from in-situ cloud probe measurements with concurrent airborne Lidar, Atmos. Meas. Tech., 15, 6447-6466, https://doi.org/10.5194/amt-15-6447-2022, 2022.

Gapp, Nicholas, David J. Delene, Jerome Schmidt, and Paul Harasti, Comparison of Concurrent Radar and Aircraft Measurements of Cirrus Clouds, Journal of Atmospheric Sciences, in review (JAS-D-24-0014), 2024.

Nairy, Christian M., David J. Delene, Jerome M. Schmidt, Paul R. Harasti, Emma Järvinen, Case Study of Chain Aggregates in Florida Cirrus Cloud Anvils from Electrified Thunderstorms. Journal of Geophysical Research: Atmospheres. In Review 2026.

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, 2026: In situ Observations of Ice Crystal Chain Aggregates in Winter Storms. Geophysical Research Letter, 53, e2025GL118365, https://doi.org/10.1029/2025GL118365.