Chain Aggregate Particles in Upper-tropospheric Clouds During IMPACTS – 15 January 2023 Case Study

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Introduction

Elongated chain aggregates comprised of ice crystals and frozen droplets have been previously observed in mid-to-upper level clouds produced by summertime convection in the sub-tropics and mid-latitudes, respectively. It is believed that strong electric fields are important for chain aggregate formation. Chain aggregates comprised of ice crystals are observed (in-situ) in upper-level clouds of an extra-tropical (ET) cyclone during the IMPACTS 15 January 2023 research flight. The properties of the ET cyclone are different compared to previously sampled summertime storms where the associated convection is shallower and less electrically active, yet chain aggregates are still observed.

- **Where are the chain aggregates observed?**
- **Where are they forming and/or being transferred from?**
- **How does the in-situ observations of chain aggregates relate to remote sensing observations from the ER-2?**

Data sets and Instrumentation

NASA P-3b Orion Research Aircraft

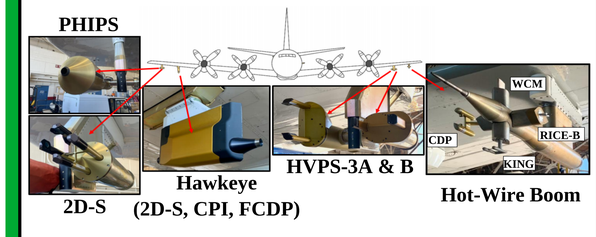
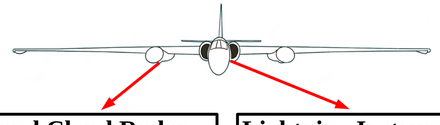


Fig. 1 Schematic of the NASA P-3b Research Aircraft and the instruments installed under the wings of the aircraft.

NASA ER-2 Research Aircraft



W-Band Cloud Radar System (CRS) | **Lightning Instrument Package (LIP)**

Fig. 2 Schematic of the NASA ER-2 Research Aircraft and two of the instruments installed on the aircraft (CRS and LIP).

15 January 2023 Observations

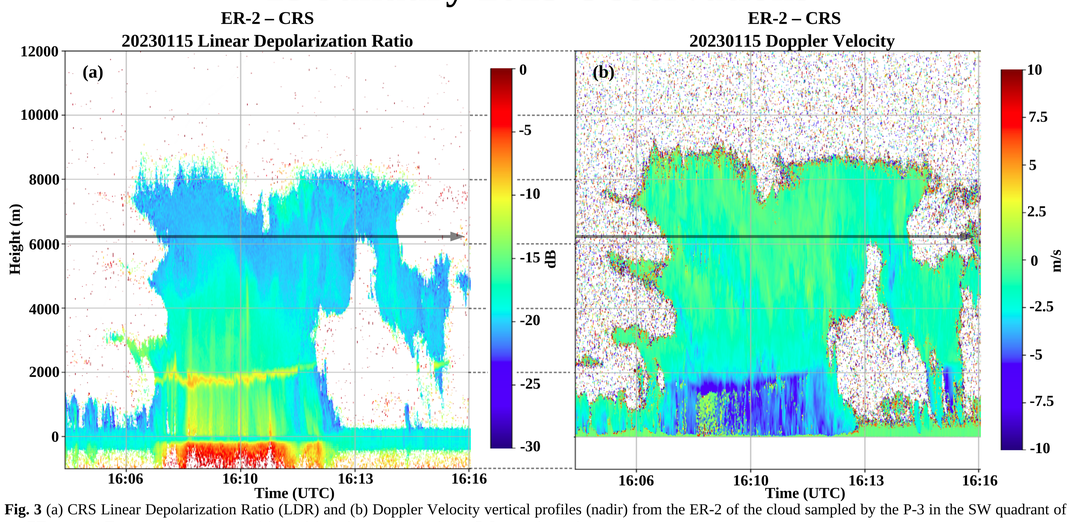


Fig. 3 (a) CRS Linear Depolarization Ratio (LDR) and (b) Doppler Velocity vertical profiles (nadir) from the ER-2 of the cloud sampled by the P-3 in the SW quadrant of the ET cyclone. The black arrow in both (a) and (b) depicts the approximate P-3 sampling altitude.

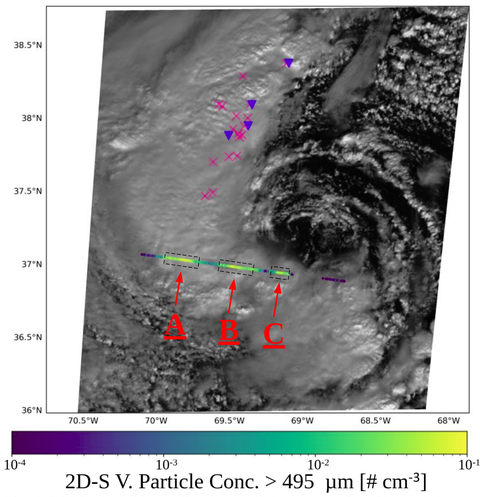


Fig. 4 GOES-16 visible satellite image (0.64 μm wavelength) on 15 January 2023 at 16:19 UTC. Cloud/Intra-cloud (pink 'X') and cloud-to-ground (blue diamond) lightning stroke data from National Lightning Detection Network (NLDN) is overlaid. Also overlaid is the P-3 aircraft flight track where the colors represent the 2D-S vertical particle concentration of particles greater than 495 μm.

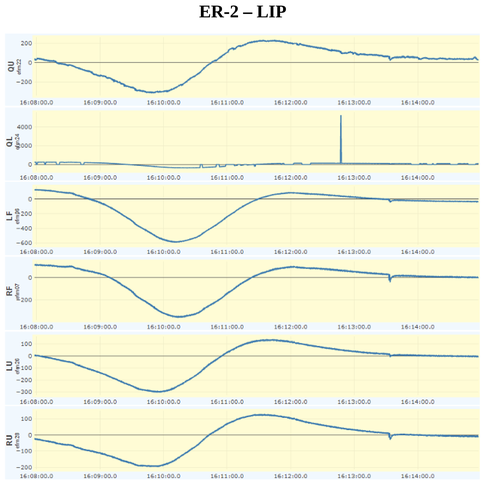


Fig. 5 Lightning Instrument Package (LIP) preliminary, raw data from the rotating-vane electric field mills (QU, QL, LF, RF, LU, RU) on the ER-2 aircraft, which provides the three-dimensional components of the electric field. The LIP time-series corresponds to the ER-2 overpass. Rotating-vane measurements are in V m^{-1}.

- ER-2 leg is from west to east above the P-3 during the 16:05-16:20 UTC leg.
- P-3 flying near cloud top (6.3 km AGL; mean temperature: -25 ± 2.5 °C).
- The ER-2 is directly above the P-3 at approximately 16:12 UTC.

- P-3 flying in relatively low LDR (-18 to -22 dB); vert. velocities between -2.5 to 2.5 m s^{-1} (Fig. 3a-b).
- Previous work of in-situ observations in Florida cirrus anvils show that a high percentage of particles > 495 μm (observed by the PHIPS) are chain aggregates. When applied to the 15 January 2023 case, three area maximums are observed (**A**, **B**, & **C** in Fig. 4).
- LIP data from the ER-2 detects electrical signal (not from lightning) below the aircraft near the time over the overpass (Fig 5).

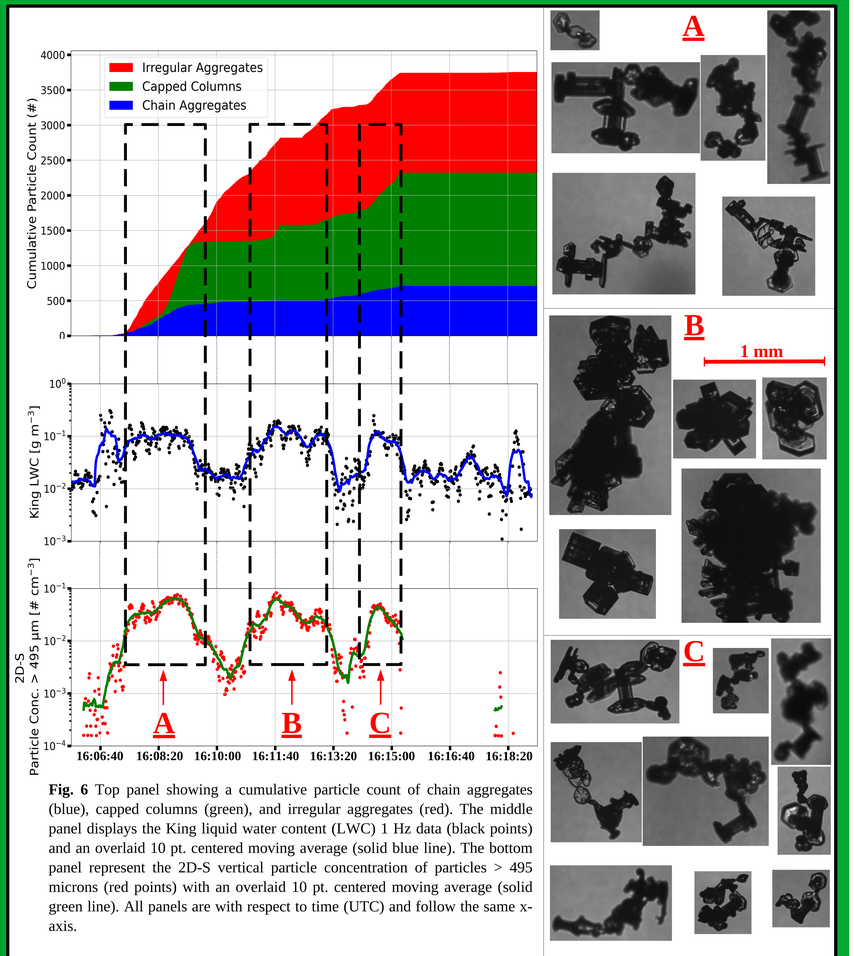


Fig. 6 Top panel showing a cumulative particle count of chain aggregates (blue), capped columns (green), and irregular aggregates (red). The middle panel displays the King liquid water content (LWC) 1 Hz data (black points) and an overlaid 10 pt. centered moving average (solid blue line). The bottom panel represent the 2D-S vertical particle concentration of particles > 495 microns (red points) with an overlaid 10 pt. centered moving average (solid green line). All panels are with respect to time (UTC) and follow the same x-axis.

Summary

- The particle concentration > 495 μm does not directly relate to the chain aggregate concentration due to contamination from irregular aggregates.
- There are more chain aggregates near the cloud edges based on the CPI classifications and the visual evidence of sublimation of the crystals.

Future Work

- Classify PHIPS images and compare to Hawkeye-CPI classification.
- More in-depth comparison to ER-2 remote-sensing data sets.
- Look at ER-2 overpass at 17:19 UTC where the P3 observed more chain aggregates at 4.4 km AGL (T = -13.5 to -9.8 °C).
- Look into more flights where chain aggregates are observed
- Find NULL cases.

Acknowledgments

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