#### UNDUNIVERSITY OF NORTH DAKOTA

# Chain Aggregate Particles in Mid-to-upper Tropospheric Clouds during IMPACTS – 15 January 2023 Case Study

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# **Motivation for Research**

- The chain aggregation process is still not well understood
  - Where/How?
  - Inconsistencies between cloud chamber experiments and aircraft observations.
  - Lack of representation in atmospheric cloud models.
- Influence on cloud radiative transfer properties (Liou 1973; Stephens *et al.* 1990; Baran 2009).



#### **Previous Chain Aggregate Observations**

#### **Cloud Chamber Experiments**

- Chain Aggregates Were Generated:
  - In High Electric Fields (Minimum Threshold: 60 kV m<sup>-1</sup>)
  - In Temperatures Between -5 and -37  $^{\circ}\mathrm{C}$
  - Ice Crystal Concentrations Between 3 and 4  $\times$  10  $^{6}\,m^{\text{-3}}$
  - Ice Crystals Sizes Between 30 to 50  $\mu m$
- Aggregation found to be temperature-dependent with electric fields.

#### **Aircraft Observations**

- Chain Aggregates of Pristine Ice Crystals Observed
  - Mid- to upper-level clouds produced by continental convection in the tropics and sub-tropics.
  - -25 to -65 °C
- Chain Aggregates of Frozen Droplets Observed
  - Continental Convection in the Midlatitudes.
  - -13 to -60 °C
  - 3

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Chain Aggregates generated in a **cloud chamber** Adapted from Saunders and Wahab, 1975.



PHIPS images (in-situ) of chain aggregates comprised of ice crystals found in cirrus anvil clouds during the CapeEx19 field campaign. Adapted from Nairy, 2022.



Chain aggregates comprised of frozen droplets observed (in-situ) in mid-latitude cirrus anvil clouds. Adapted from Stith *et al.* 2014.

# **Recent Chain Aggregate Observations**

#### • IMPACTS - 15 January 2023 Research Flight

- Chain Aggregates observed in-situ (P-3) during the 16:06:15–16:16:00 UTC flight leg through SW quadrant of an ET-cyclone off the Atlantic Coast.
- $\circ\,$  NASA ER-2 Research Aircraft overpass also conducted during this time.





Hawkeye-CPI images of chain aggregates obtained during the IMPACTS 15 January 2023 16:06:15-16:16:00 UTC flight leg

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## **Dataset/Instrumentation**

• <u>Investigation of Microphysics and Precipitation</u> for <u>Atlantic Coast-Threatening</u> <u>Snowstorms (IMPACTS).</u>

- NASA P-3b Orion
  - Hawkeye-Cloud Particle Imaging (CPI) and 2D-Stereo
  - Turbulent Air Motion Measurement System (TAMMS)
- NASA ER-2
  - CRS (W-band) Reflectivity (dBZ), Vertical Velocity, & Linear Depolarization Ratio (LDR)



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

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# Objectives

- Where are the chain aggregates observed.
  - Manually classify particles using Hawkeye-CPI for the 16:06:15-16:16:00 flight leg.
- Relate chain aggregates to the ER-2 Cloud Radar System (CRS) observations.
  - Relate where they are observed (Hawkeye-CPI) to the 2D-S probe.



#### 15 January 2023 Case Study - Background

13 UTC 01/15



4-panel plot showing composite reflectivity (top-left), VIS/IR GOES-16 satellite imagery (top-right), 00 UTC upper-air analysis (bottom-left), and 12 UTC surface analysis (bottom-right).

Animated loop showing GOES-16 (VIS CH01) in 30-minute intervals (15:00-20:30 UTC) over eastern CONUS and western Atlantic. Overlayed are flight tracks from the P-3 aircraft (red) and the ER-2 aircraft (blue).







# Need to Analyze More Cases...

...to relate chain aggregates to radar/lidar observations.

- Chain aggregates observed during 17 research flights in 2022 & 2023.
  - Observed on almost every science flight in 2023!
- However, more cases → more CPI images to classify → very time consuming!
- Only interested where chain aggregates are located  $\rightarrow$  need an automated chain aggregate detection method.
  - Utilize common chain aggregate properties to segregate them from the overall particle population
- Apply Method to other in-situ probes (e.g. 2D-S) with larger sample volumes to establish a less uncertain chain aggregate detection scheme.







**Applying CPI D**<sub>max</sub> & Area Ratio Thresholds on CPI & **2D-S** particles

 $10^{-1}$ 



#### Summary

- Approximately 800 Chain Aggregates (8%) classified during the 16:06:15-16:16:00 flight leg on 15 January 2023.
- Chains are similar to those observed in cloud chamber experiments and previous field campaigns.
- Downstream of TROWAL where electrification is occurring.
  - Mixed vertical motion.
  - Small scale convective areas.
- Using  $D_{max}$  and area ratio thresholds does a good job segregating chain aggregates from the total particle population.



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# **Future Work**

- 17 number of flights from 2022 & 2023 observed chain aggregates.
  - Assessment across multiple IMPACTS flights.
  - Enable relating chain aggregate concentrations to ER-2 radar/lidar measurements.
- Apply circularity measurement to 2D-S for a more robust chain aggregate concentration.



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### **References & Acknowledgements**

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Thank you.

#### EXTRA SLIDES





