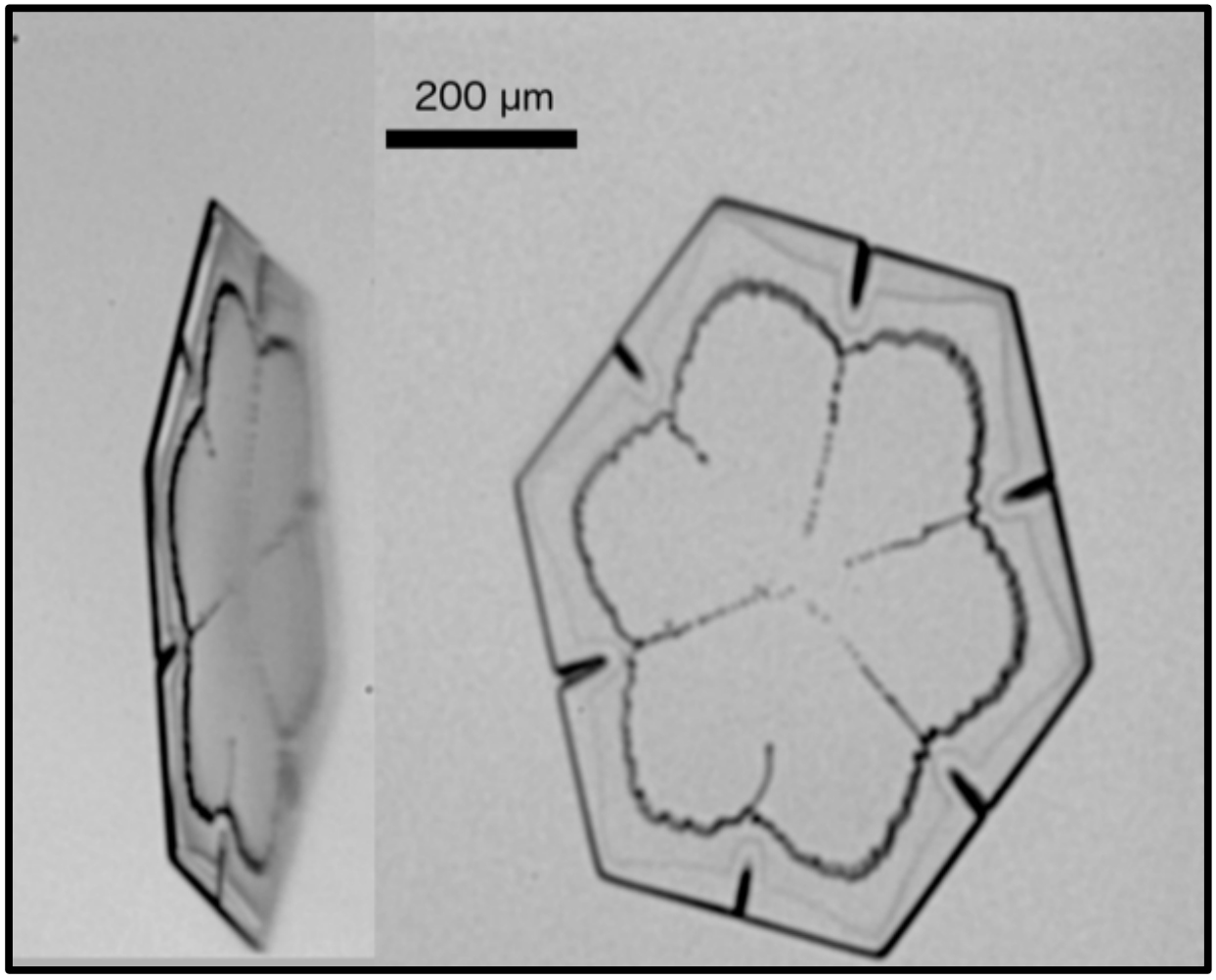
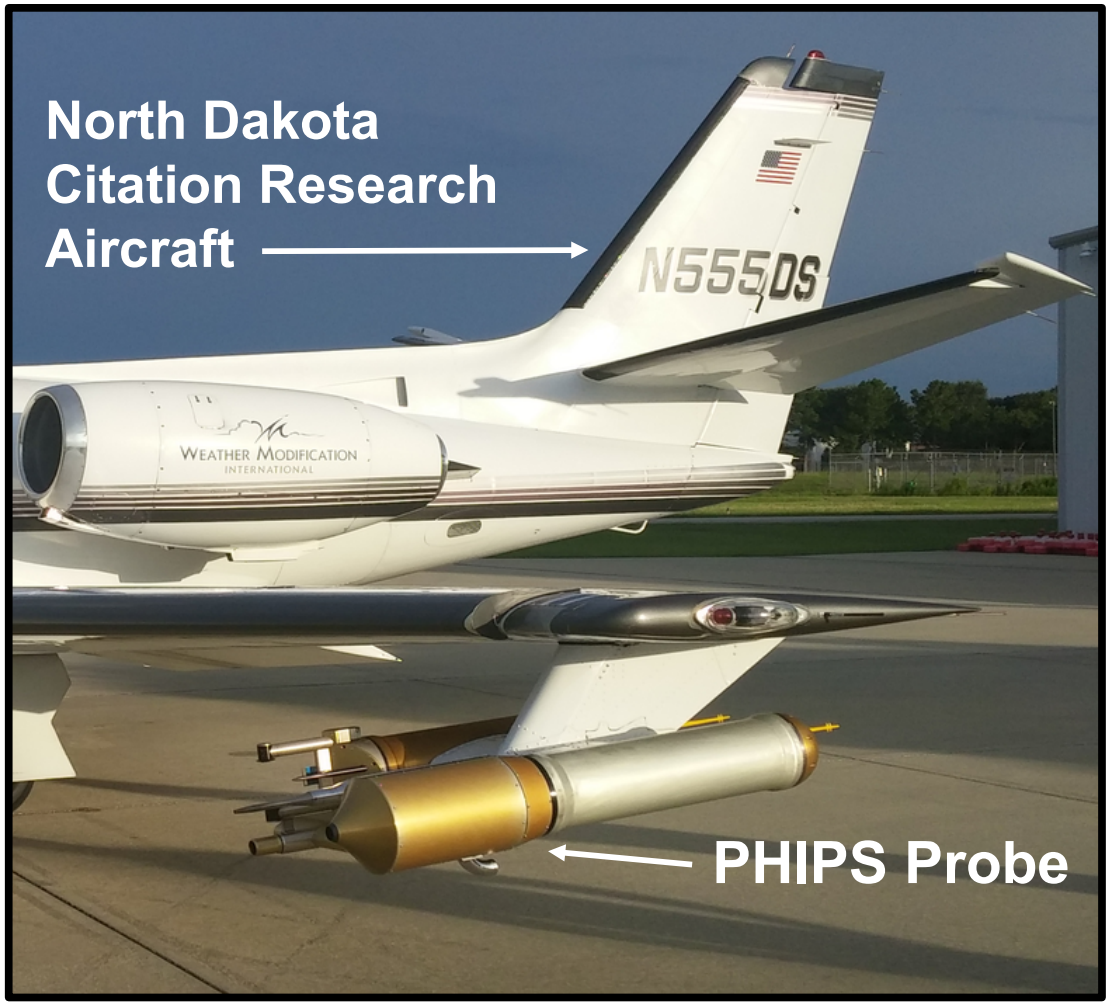
Ice Crystal Growth



PHIPS images of plate crystal.

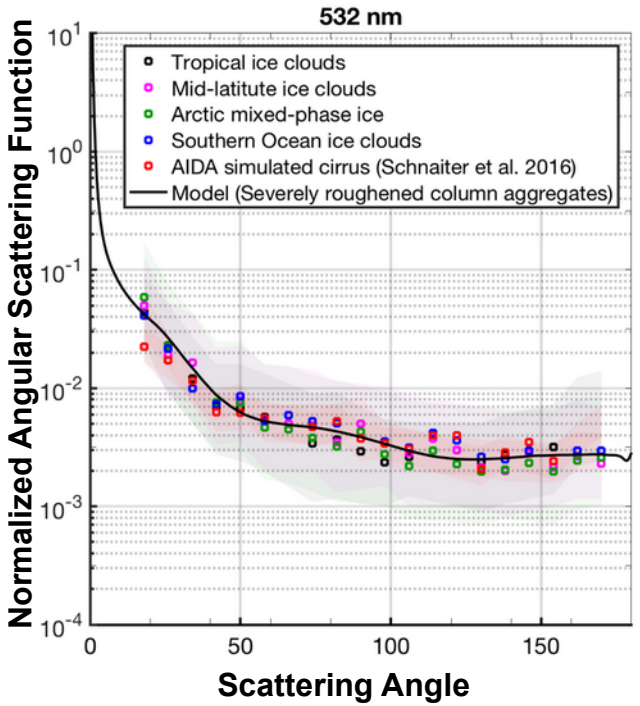
Particle Habit Imaging and Polar Scattering (PHIPS) Probe



- Measure the angular light scattering function of individual cloud particles that are identifiable as belonging to a particular habit.
  - → Improved remote sensing observations.
- Obtain high resolution stereo-graphic images with sufficient detail to improve understanding of riming and aggregation processes.
  - → Improved cloud micro-physical modeling.
- Provide reliable phase identification on small and intermediate sized cloud particles.
  - → Improved understanding of precipitation.

Measurements and Observations of the PHIPS Probe

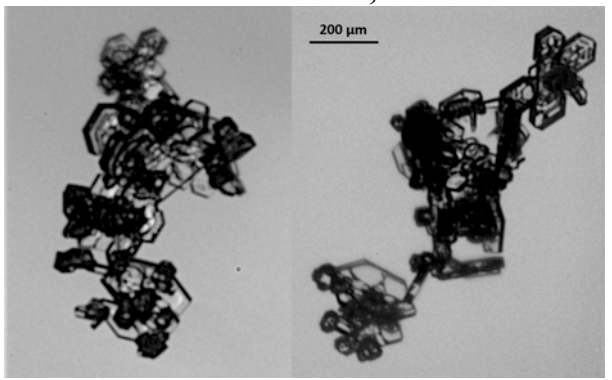
Angular Light Scattering Function



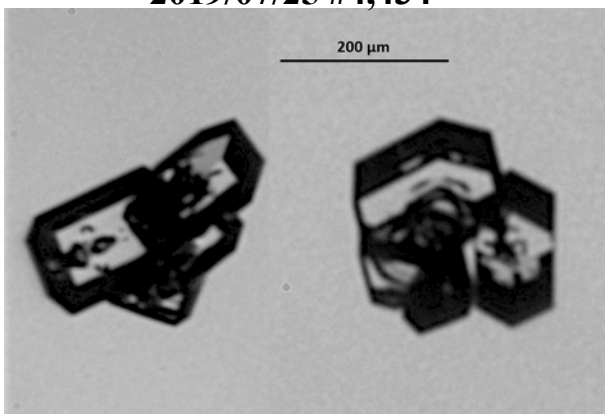
Averaged angular scattering functions from different campaigns, which was used to validate the MODIS C6 ice optical model (Järvinen et al., 2018).

Stereo-graphic Images

2019/07/26 #5,134

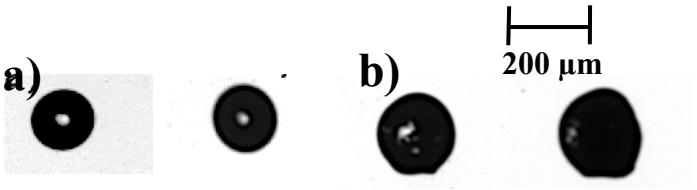


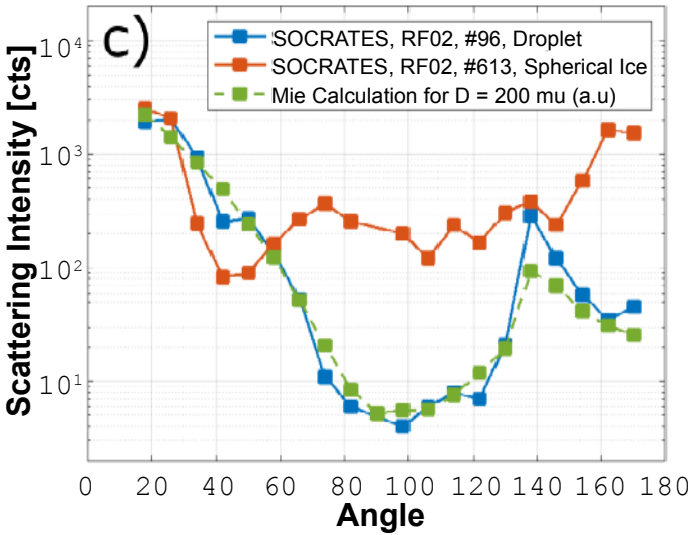
2019/07/25 #4,434



Stereo image pairs obtained within Cirrus cloud anvils over Florida.

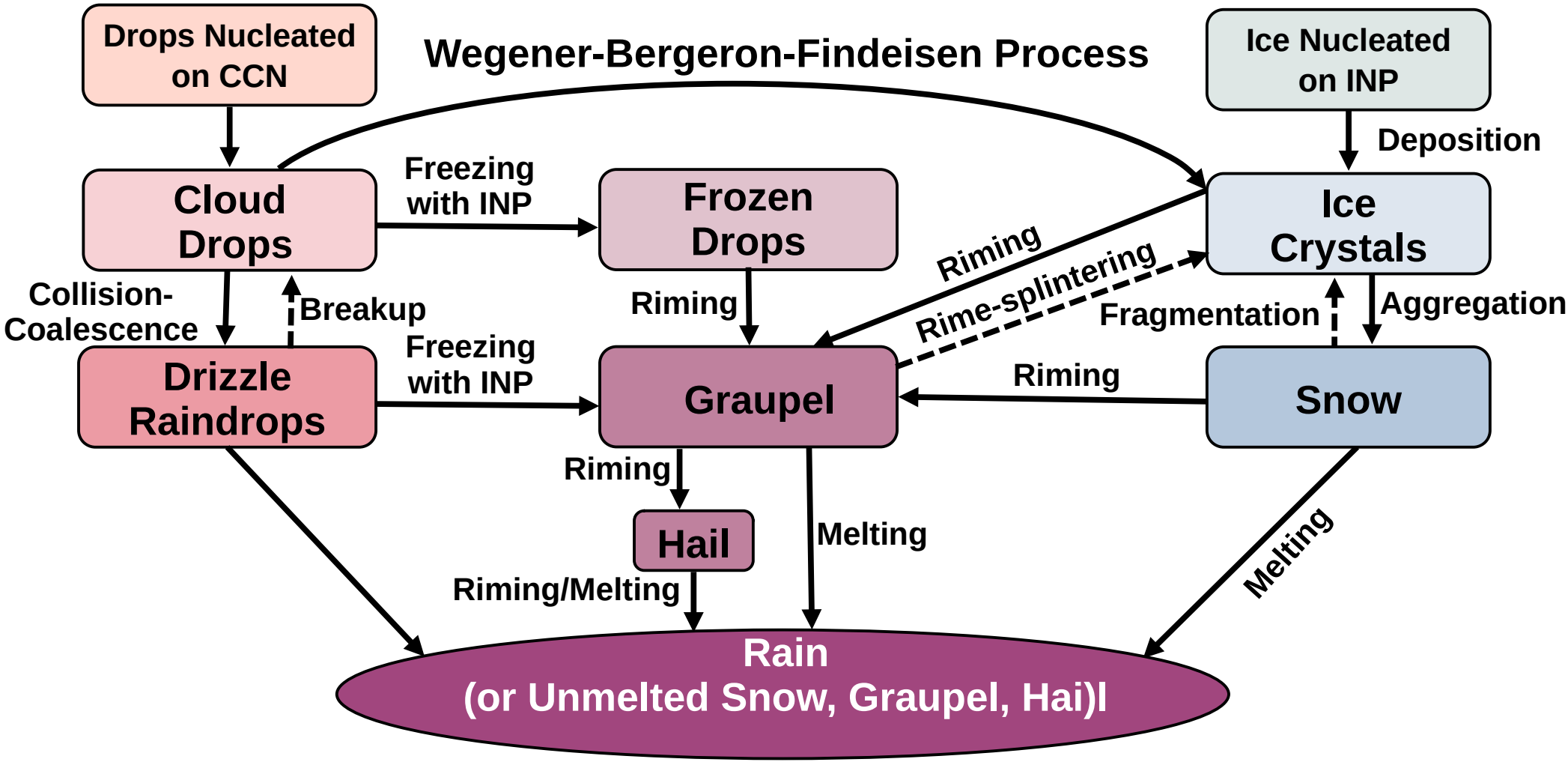
Phase Identification





Stereo image pairs of a droplet (a) and a quasi-spherical ice particle (b), and the corresponding angular scattering function (c) (Waitz et al., AMT in preparation).

Microphysical Processes that Produce Precipitation



Ice Crystal Types (Many Methods)

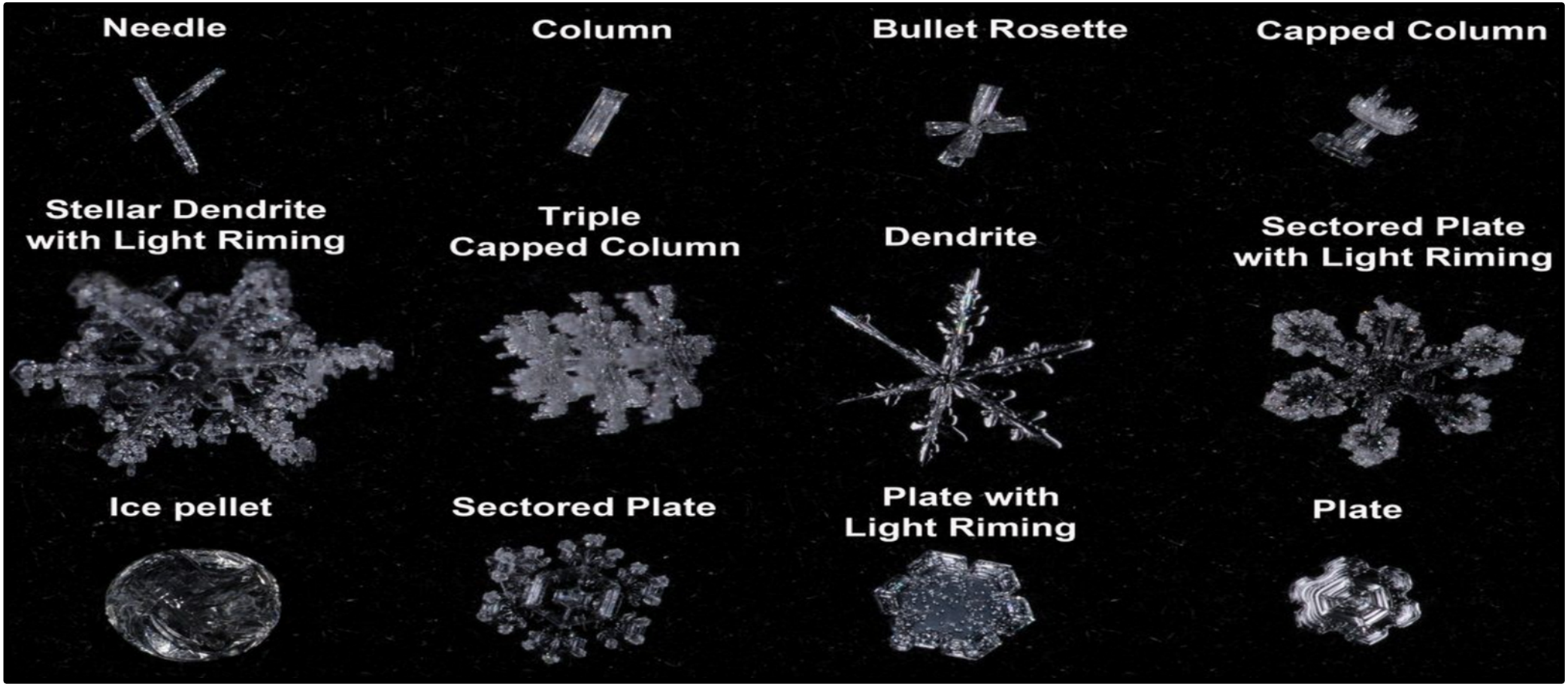
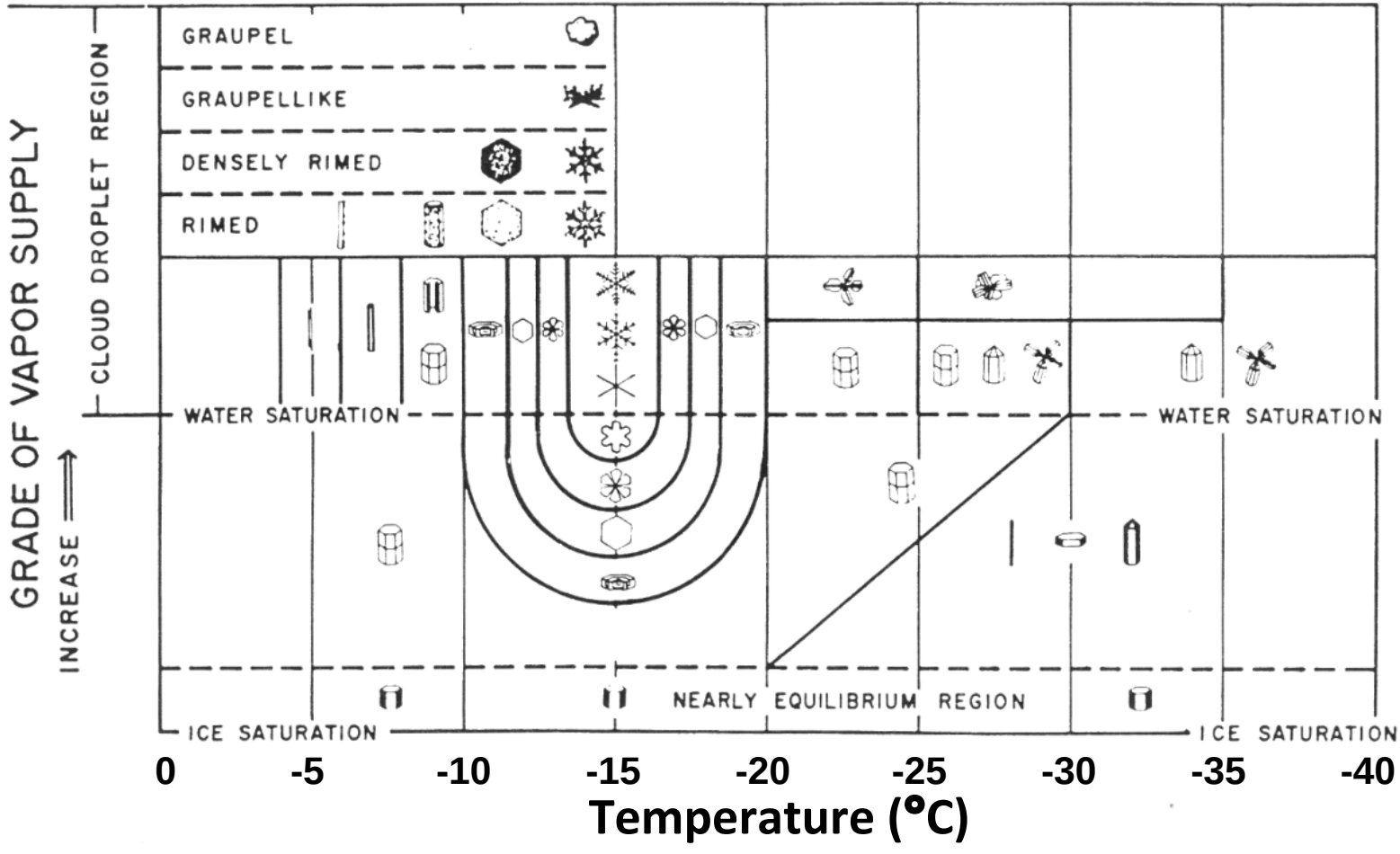


Image adapted from University of Manitoba.

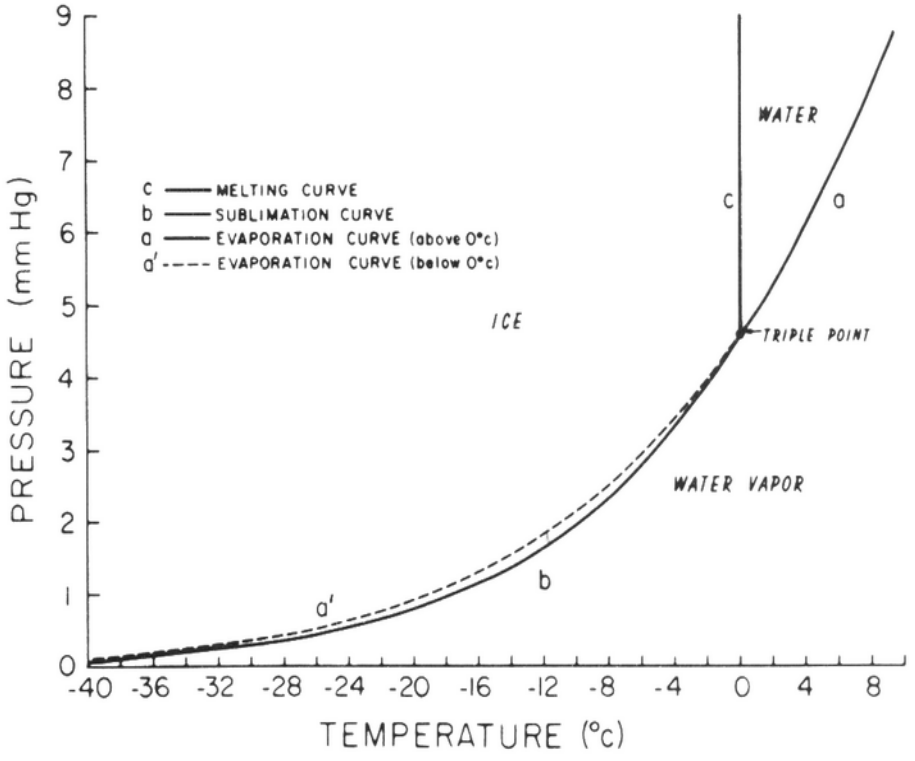
Crystal Habit Formation



Habit depends on air temperature and vapor supply during formation.

Clausius Clapeyron Equation

- Previous discussion related the vapor pressure in equilibrium with a pure, plane water (liquid) surface to temperature.
- If the water is frozen, however, the water molecules are held more securely to the surface and the amount of vapor in equilibrium with that surface is less.



Difference Affects Growth Rates

High Vapor Pressure

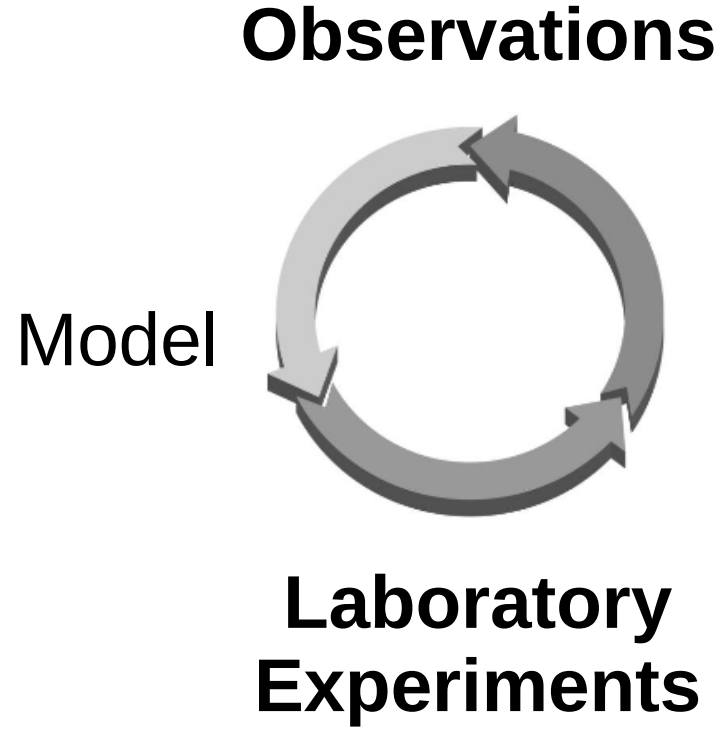
Lower Vapor Pressure

Mixed Cloud (Ice and Liquid)

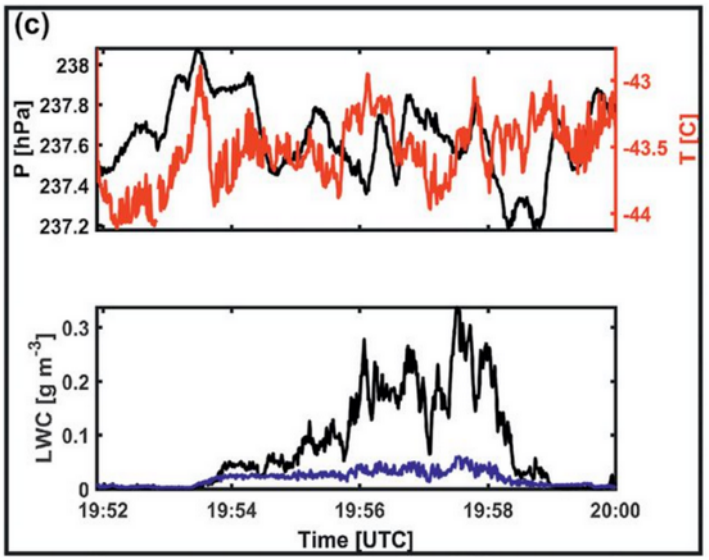
- Ice crystals will grow rapidly.
- Water droplets will evaporate.
  - Large fraction of the ice crystals falling as precipitation tend to be stellar types, even though they form in a very narrow region of the temperature/ humidity conditions possible in clouds.
  - Also get a large number of plate types of crystals.

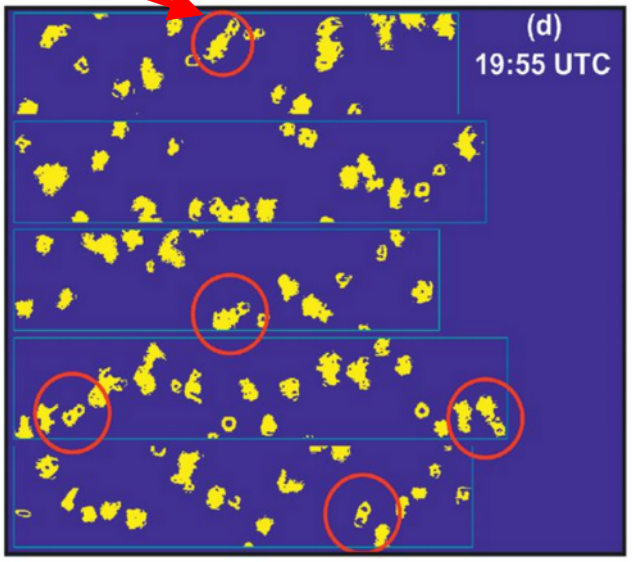
The Scientific Method

- **Observations**
  - The starting point of the scientific method.
- Questions
  - Why do we observe it?
- **Hypothesis**
  - What is a possible answer?
- **Laboratory Experiments**
  - Control variables during observations.
- Conclusion
  - Does the evidence supports or does not support the hypothesis.



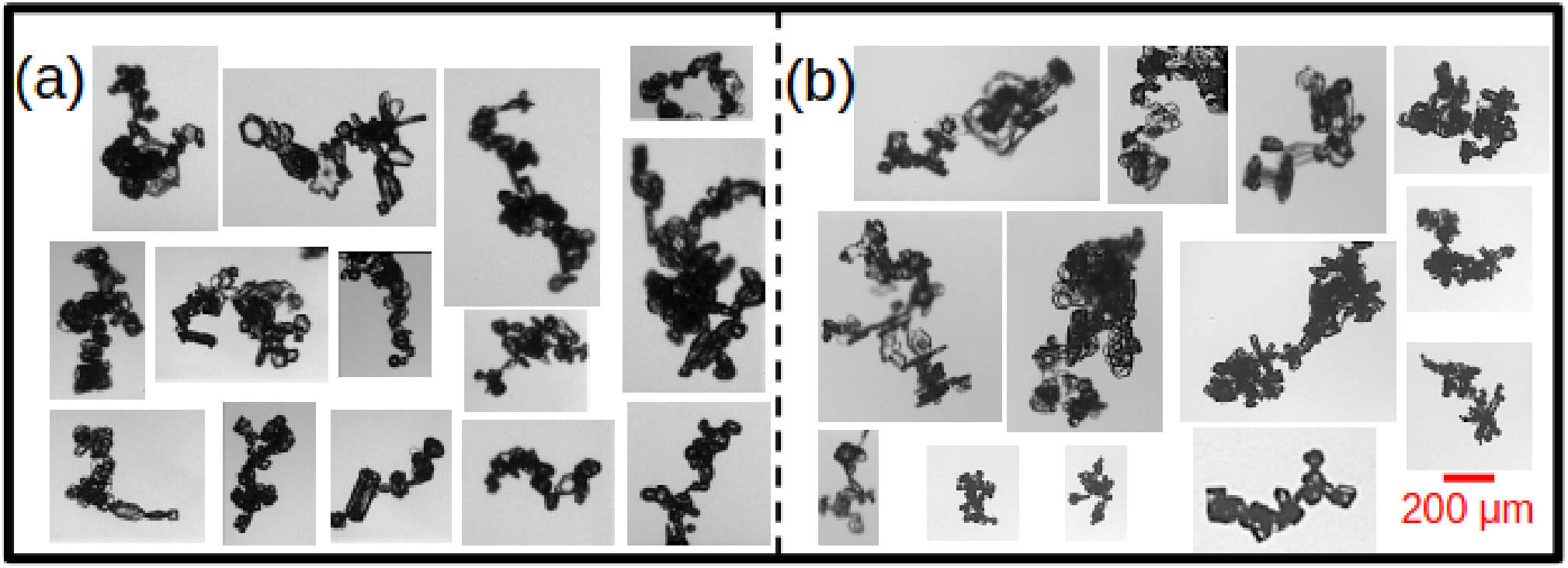
Chain-like Aggregates





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, 2019: Radar Detection of Individual Raindrops, Bulletin of the American Meteorological Society, 100, 2433-2450, https://doi.org/10.1175/BAMS-D-18-0130.1.

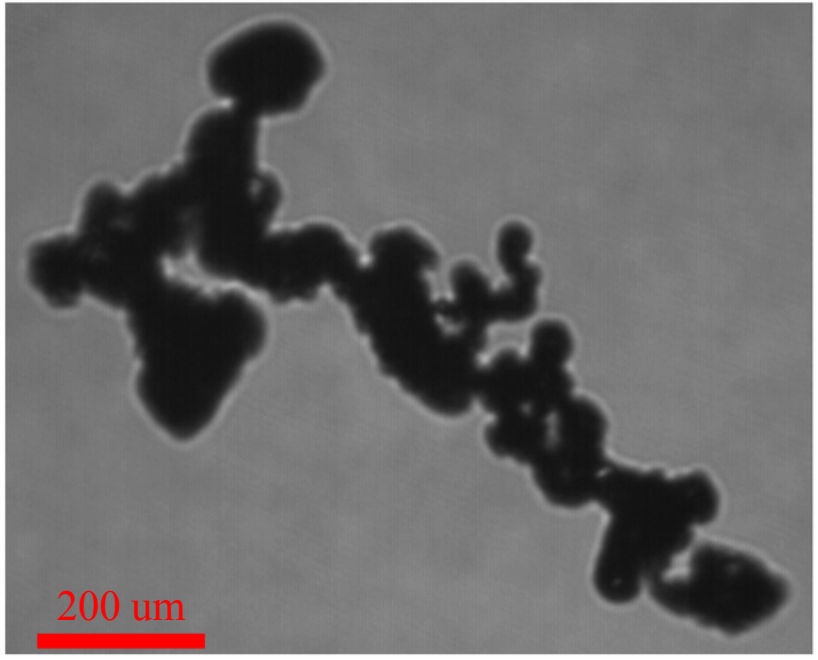
Chain-like Aggregates



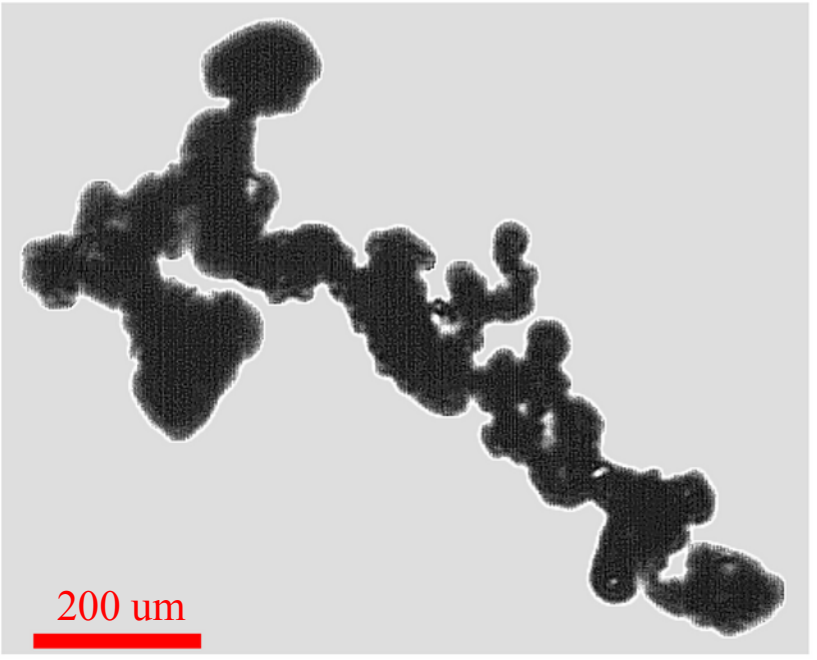
A collage of Particle Habit Imaging and Polar Scattering (PHIPS) probe images of chain like aggregates observed during (a) CapeEx19 and (b) IMPACTS field projects. Images are courtesy of Dr. Emma Järvinen of University of Wuppertal.

IMPACTS Chain-like Aggregate

Original Image
IMPACTS_HawkeyeCPI_20220117143115143607328_003617_C1.png



Enhanced Image

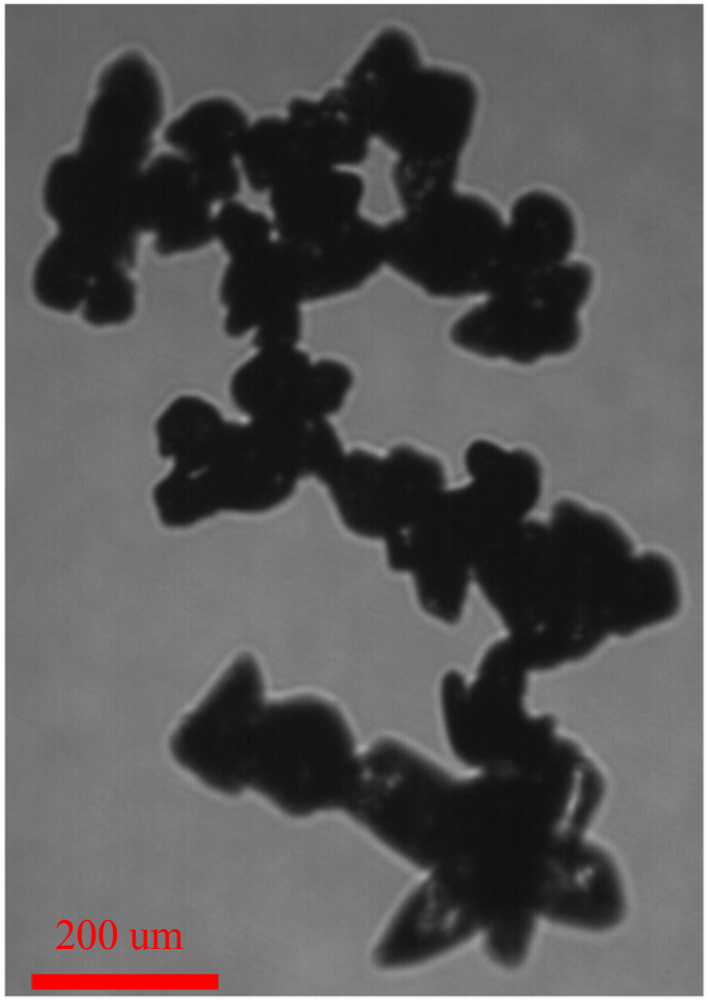


Courtesy of Christian Nairy, Ph.D Student, University of North Dakota.

IMPACTS Chain-like Aggregate

Original Image

IMPACTS_HawkeyeCPI_20220117143115143640911_004040_C1.png



Courtesy of Christian Nairy, Ph.D Student, University of North Dakota.

Enhanced Image

IMPACTS Chain-like Aggregate

Original Image

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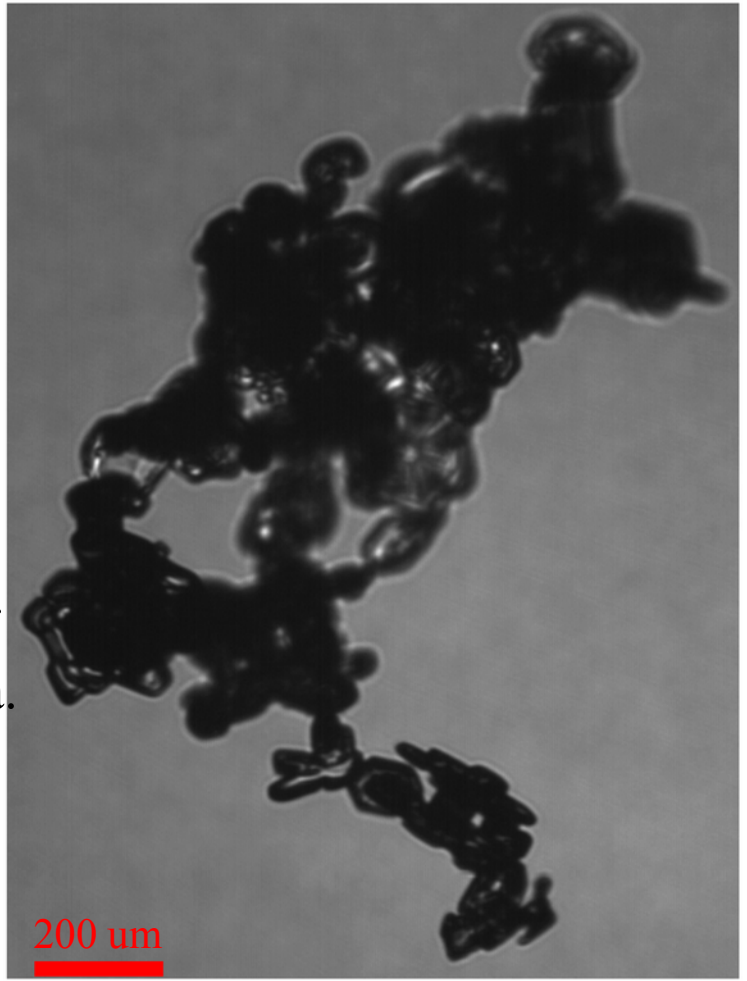
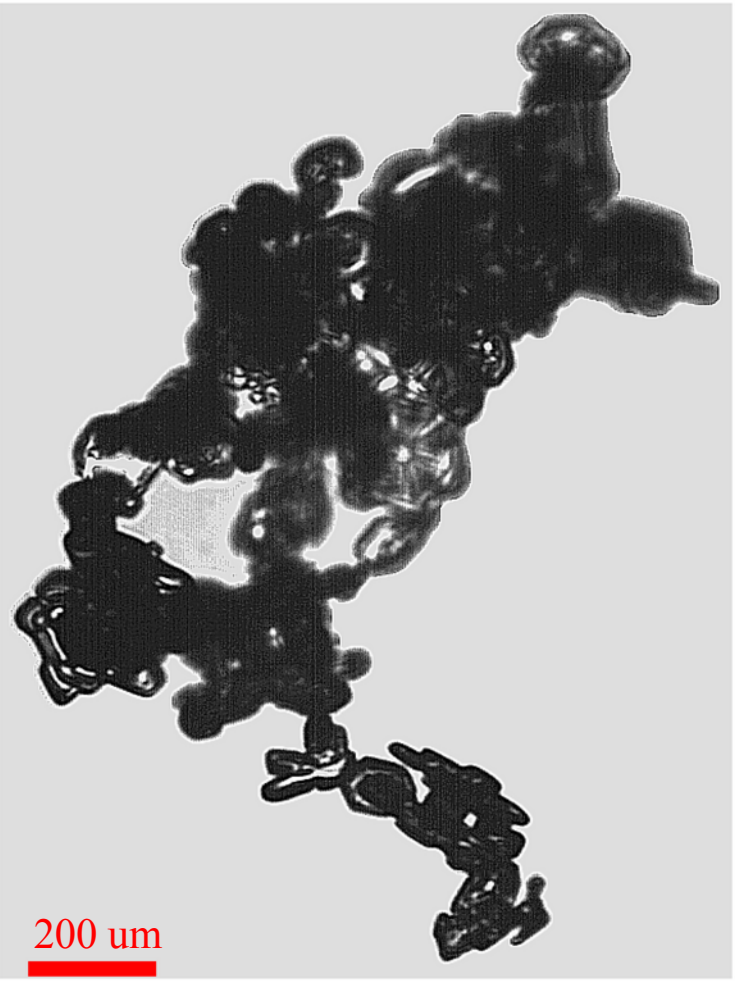


Courtesy of Christian Nairy, Ph.D Student, University of North Dakota.

Enhanced Image



IMPACTS Chain-like Aggregate

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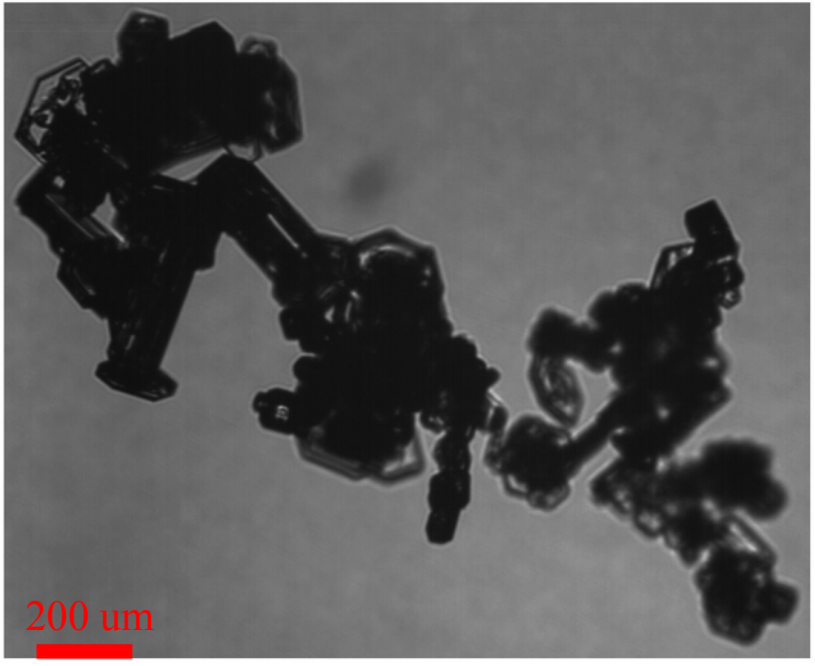

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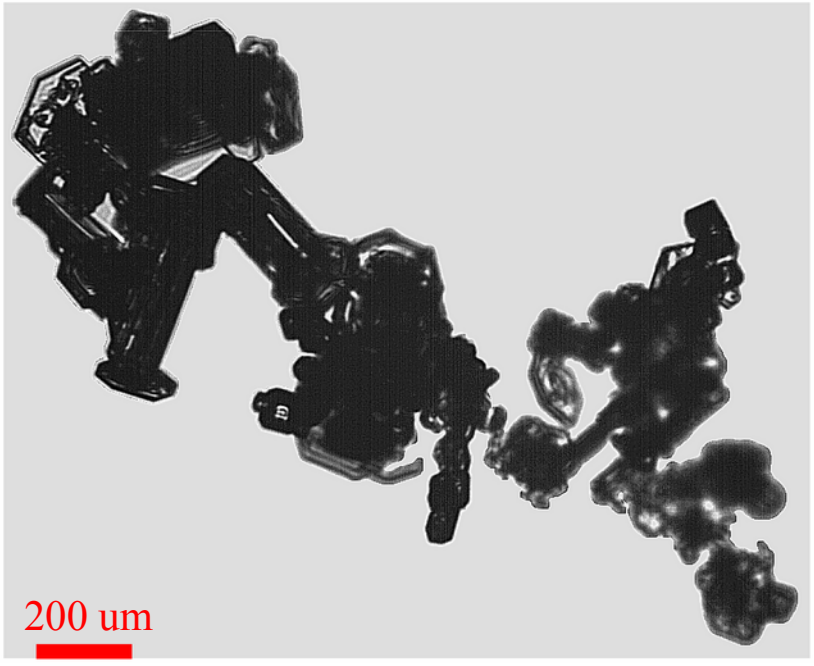

Courtesy of Christian Nairy, Ph.D Student, University of North Dakota.

IMPACTS Chain-like Aggregate

Original Image
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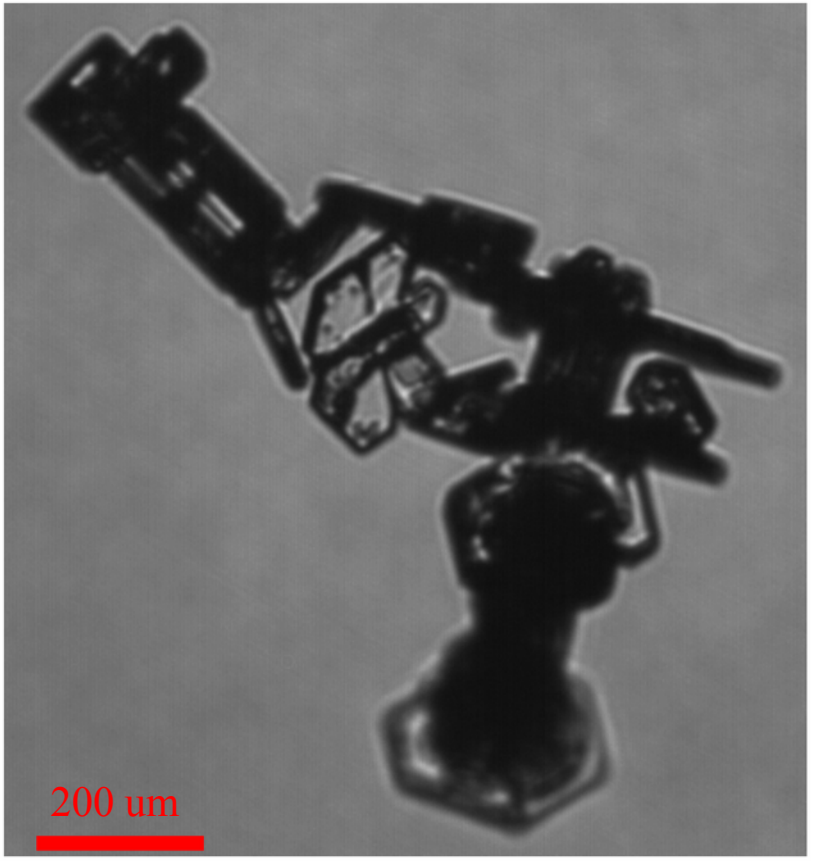

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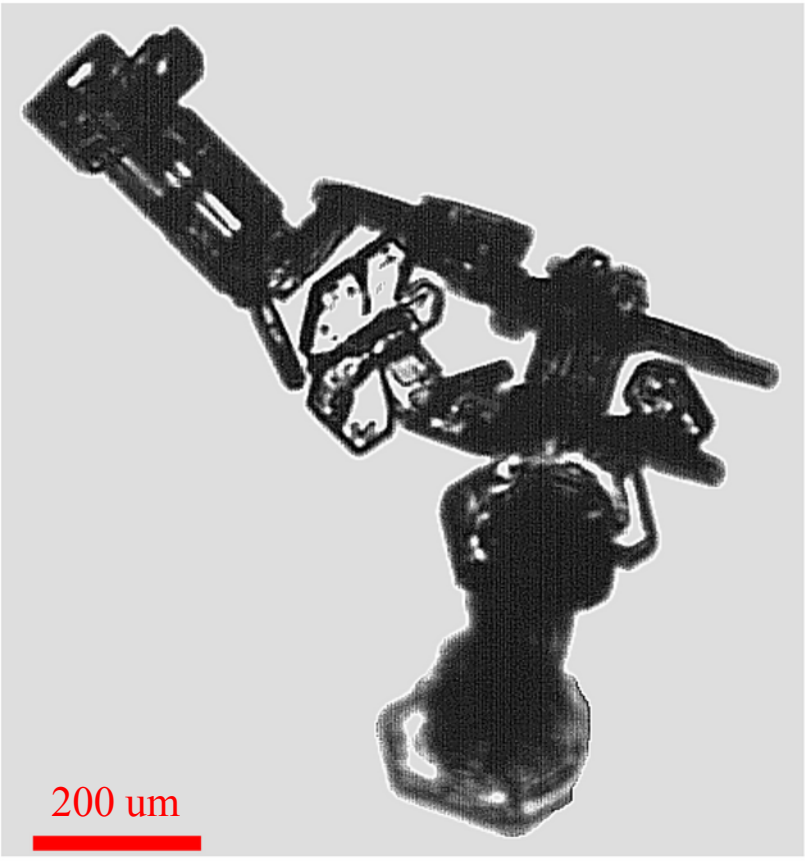

Courtesy of Christian Nairy, Ph.D Student, University of North Dakota.

IMPACTS Chain-like Aggregate

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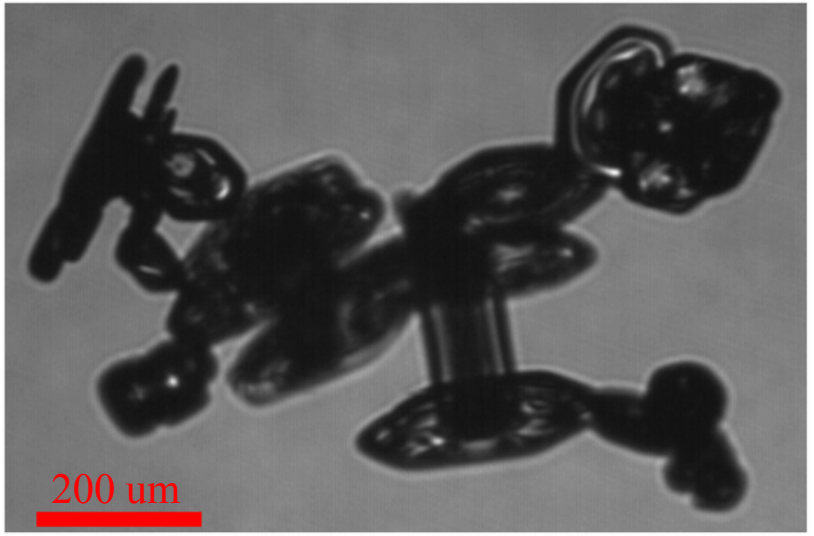

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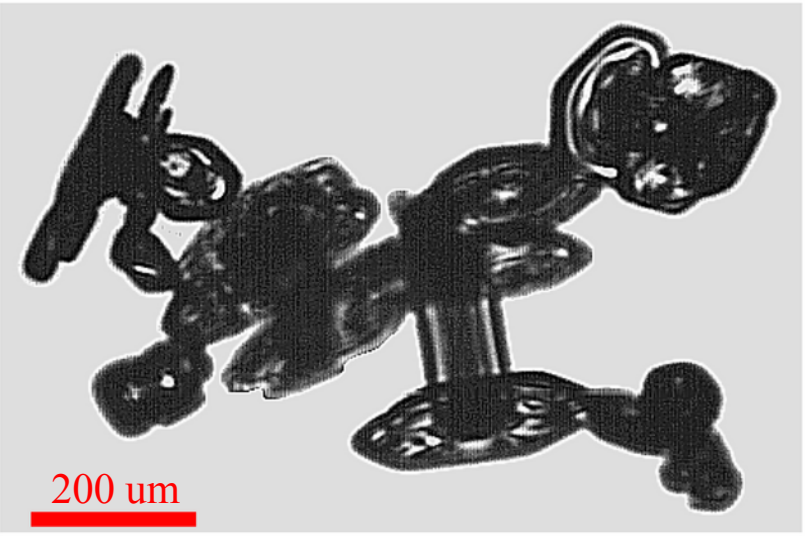
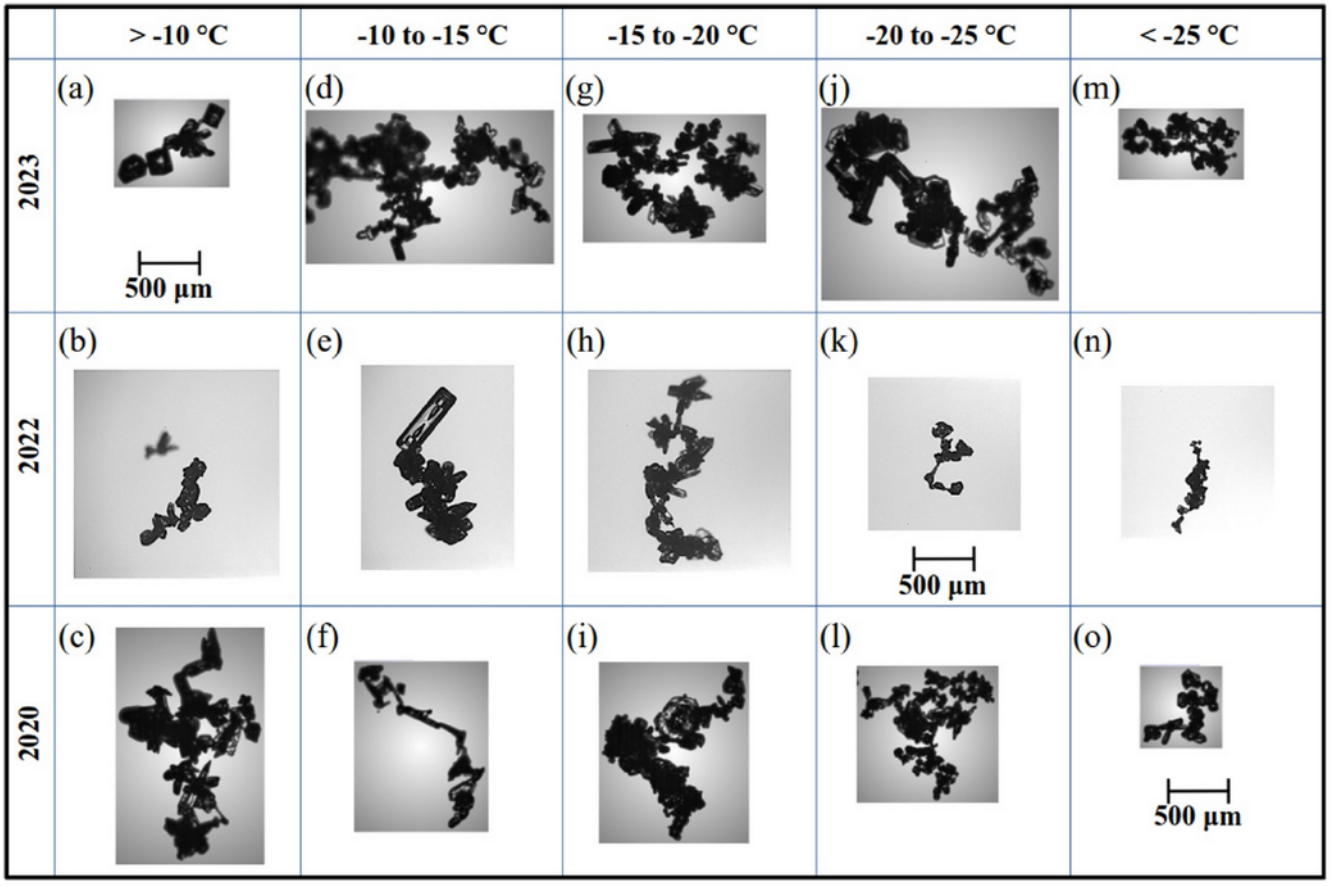


Courtesy of Christian Nairy, Ph.D Student, University of North Dakota.

Ice Crystal Chain Aggregates in Winter Storms



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.