Implications of Precipitation Particle Properties for Improved Understanding of Ice-Nucleating Particles in West Texas

West Texas A&M

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Goals & Background

- This study was conducted to assess precipitation particle properties; i.e., **ice-nucleating particle (INP) propensity** and **bio-speciation**.
- In this study, we looked into the **44 precipitation events** observed in West Texas **throughout the year** in 2018-2019.
- The West Texas region is dominated by the semi-arid climate and deep convective clouds where INPs play a crucial role in storm formation processes (e.g., Li *et al.*, 2017; Rosenfeld *et al.*, 2008).
- INPs provide seeding-surfaces for water vapor and liquid water to deposit or condense on, enabling the emergence of ice crystals in the atmosphere through heterogeneous freezing (e.g., Vali *et al.*, 2015).
- Ice crystal growth occurs in clouds (where supercooled water and ice co-exist) through the Bergeron Process, in which ambient vapor pressure falls between saturated vapor pressure over water and lower saturated vapor pressure over ice (Bergeron, 1935), eventually precipitating to the ground often as hail particles in West Texas (**Fig. 1**).

Figure 1. Hail storm sample collected at WTAMU.

Precipitation Measurements

- The **OTT Parsivel²** (Particle Size Velocity 2) sensor is a modern laser **disdrometer** (λ = 780 nm) that measures the size and number of hydrometeors in 0.062 - 24.5 mm with 32 diameter bins (*Tokay et al.*, 2014).
- Precipitation particles pass through the laser beam off a portion of the beam, reducing the output voltage - this determines the particle size.
- A disdrometer is used to look into **the relationship between INP concentration and size of precipitation particles**.
- Shown in **Fig. 2** are how we deployed our disdrometer on the roof-top of the 50 ft building, where we conducted our precipitation sampling activities, and measured annual data.

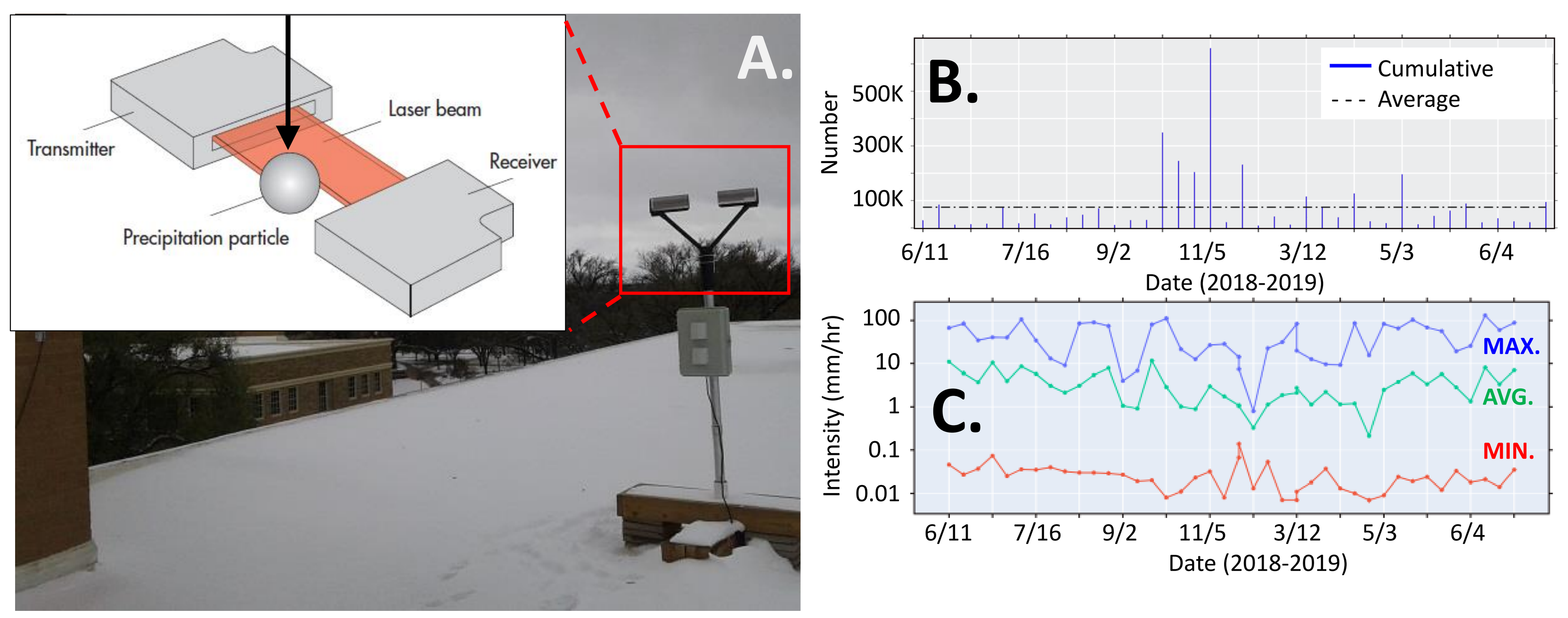


Figure 2. Deployment of the OTT Parsivel² disdrometer on the roof of WTAMU Natural Science Building (NSB), ~50 ft above ground level (A), as well as the measured number of hydrometeors (B) and precipitation intensity in mm/hr (C).

- Shown in **Fig. 3 b**elow represents particle size distribution for four different precipitation types, determined through observation.

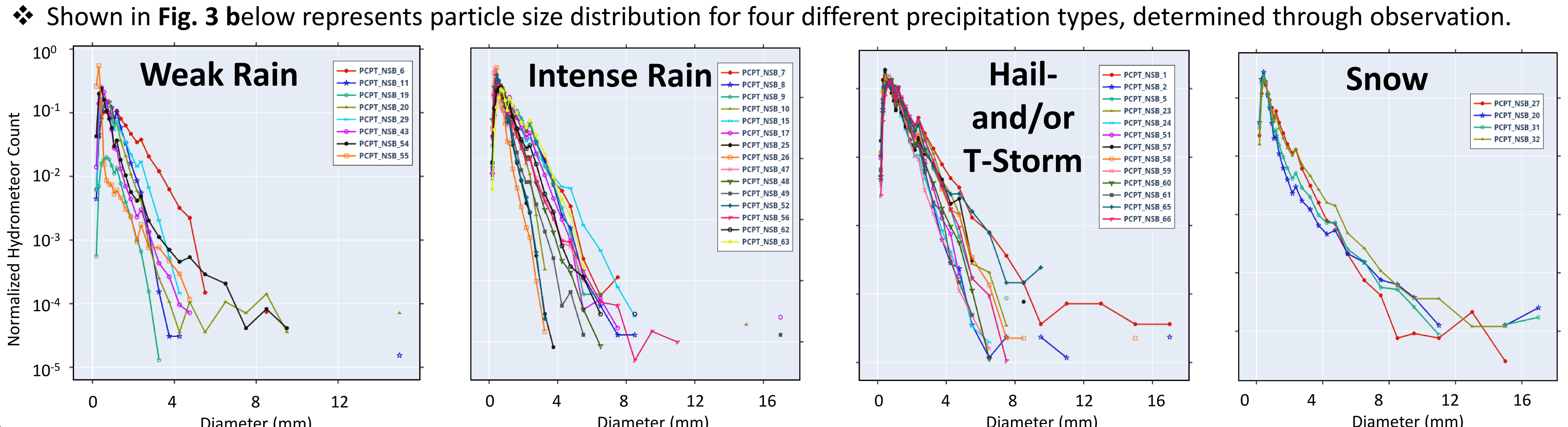


Figure 3. Size distributions of precipitation particles from 44 precipitation events, categorized into four groups.

Precipitation Samples

- All 44 precipitation samples were collected by placing sterilized polypropylene tubes on an elevated platform on the roof of the Natural Science Building (NSB).
- The rooftop is completely exposed to the ambient air without any canopies.
- After some amount was accumulated, the sampling tubes were capped and refrigerated at 4 °C until the drop freeze assay measurement and metagenomics analyses would commence following Petters and Wright (2015).

Ice Nucleation Experiment

- We used an offline droplet-freezing assay instrument, the so-called **West Texas Cryogenic Refrigerator Applied to Freezing Test (WT-CRAFT)** system (Hiranuma *et al.*, 2019), to measure temperature (*T*)-resolved ice-nucleating particle (INP) concentrations at *T* > -25 °C with a detection capability of >0.001 per L of air (**Fig. 4**).
- 70 solution droplets (3 µL each) placed on a hydrophobic Vaseline layer were analyzed per experiment.
- With a cooling rate of 1 °C min^{-1}, **INP concentration** (**n_{INP}**; e.g., DeMott *et al.*, 2017) of super-microliter-sized droplets containing particles from precipitation samples were estimated as a function of *T* for every 0.5 °C presuming Cloud Water Content of 0.4 g-H_2O m^{-3}-Air as described in Petters and Wright (2015).

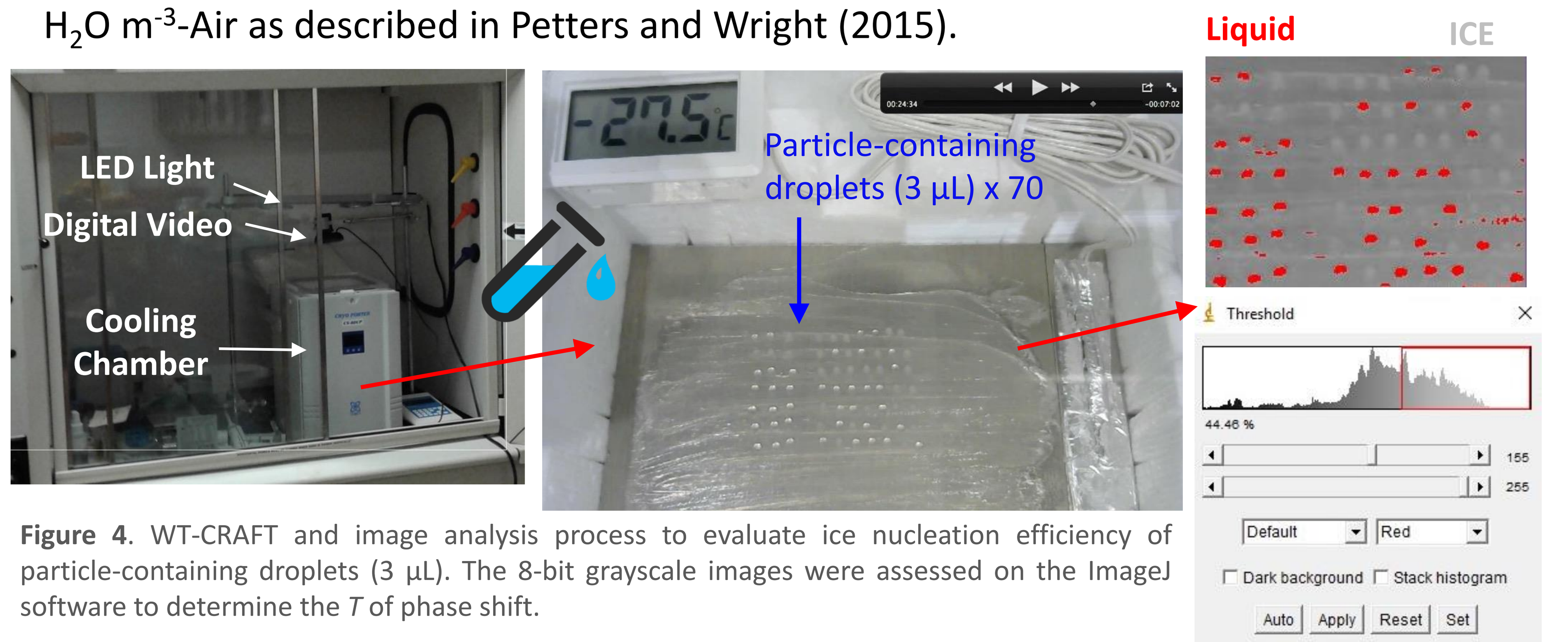
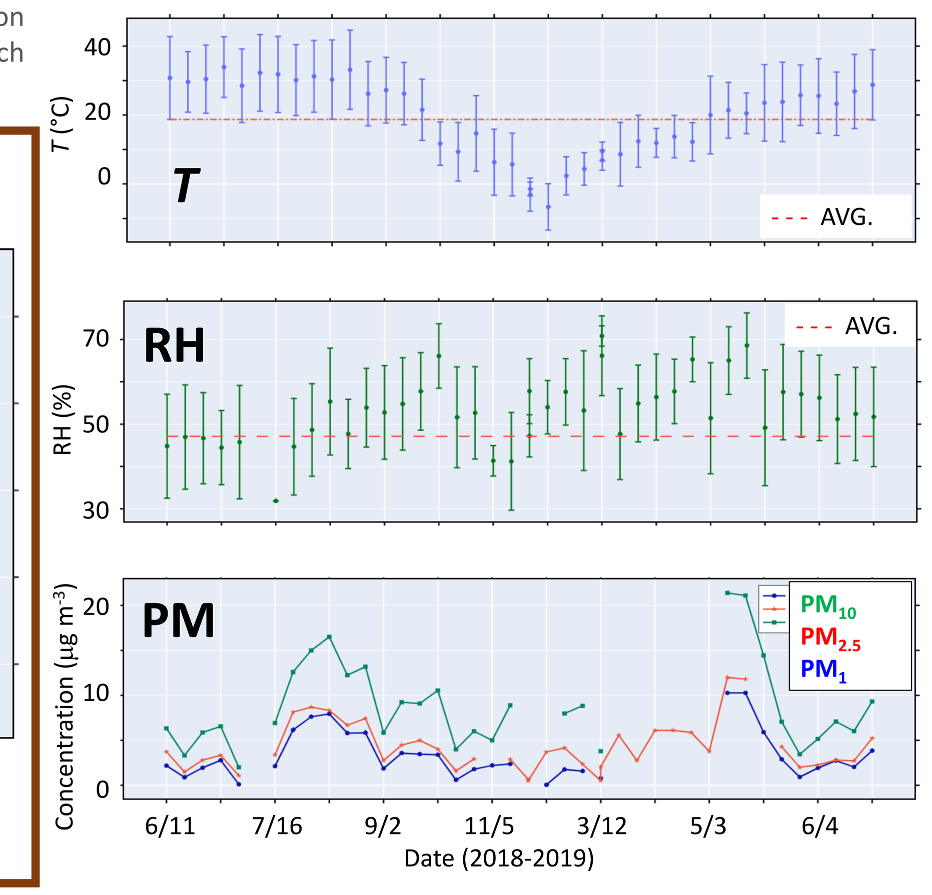


Figure 4. WT-CRAFT and image analysis process to evaluate ice nucleation efficiency of particle-containing droplets (3 µL). The 8-bit grayscale images were assessed on the ImageJ software to determine the *T* of phase shift.

Annual Ambient Conditions

- An Arduino-based IoT air quality sensor measured different air quality metrics (**Fig. 5**).
- A DFRobot PM laser dust sensor is used to obtain the concentration of suspended particulate matter (PM) with size ranges of <1, <2.5 and <10 microns.
- *T* and relative humidity (RH) are measured with a precision Bosch BME280 environmental sensor.
- We observed strong diurnal *T* cycles (not shown), and precipitation occurs when *T* is dropped - the temperature ingredient (Δ*T*) is important for precipitation enhancement.

▶ **Figure 5.** Time series of T, RH, PM concentration broken into PM10, PM2.5, and PM1.0 for each precipitation event analyzed.



INP & Metagenomics Results

- Shown below in **Fig. 6** is our results of n_{INP} time series for all 44 PCPT samples (with *T* intervals of 5 °C).
- The high temperature INPs observed at temperatures higher than ~-15 °C may be indicative of biological INPs, presumably deriving from cattle feedlots (Whiteside *et al.*, 2018 & **Figs. 7 & 8**).
- More comprehensive INP source identification in the future would be important.

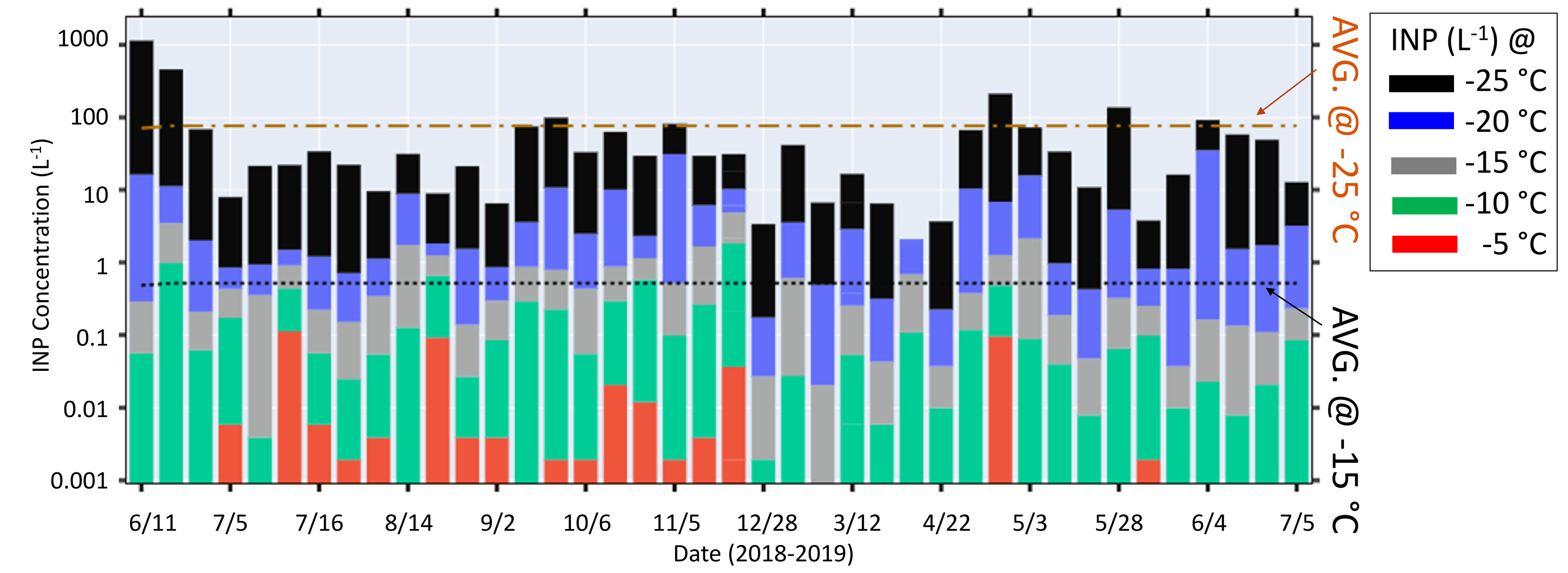
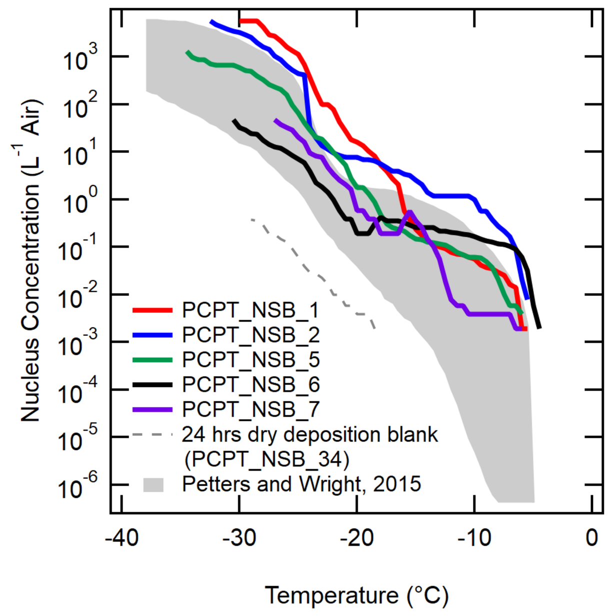
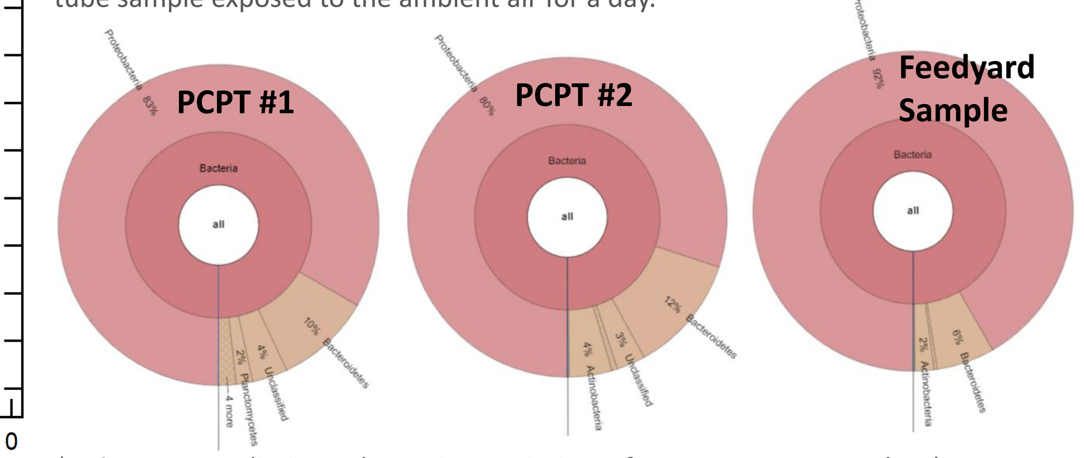


Figure 6. Time series of INP concentrations in precipitation samples collected in 2018-2019.

- By assessing the size distribution of precipitation particles (**Fig. 3**), it is notable that **giant particles (>10 mm) coincide with severe hail/thunderstorm (i.e., PCPT_NSB_1 and _2).**
- **Our spectra of INPs in severe hail/thunderstorms (Fig. 7) exhibit substantially high ice nucleation efficiency** at temperatures lower than -16.5 °C.
- Interestingly, **these spectra exceed what have been historically observed in previous study** (Petters and Wright, 2015). Intense rain properties may be the key of forming artificial precipitation in West Texas.



◀ **Figure 7.** A subset of precipitation INP spectra overlaid on top of reference spectral area (Petters and Wright, 2015) and our background spectrum – blank tube sample exposed to the ambient air for a day.



▲ **Figure 8.** Preliminary bacteria speciation of severe storm samples (PCPT #1 and #2) as well as feedyard dust samples (RTL GENOMICS, 2019).

Summary & Outlook

1. More INPs are observed when the intensity of precipitation exceeds 45 mm/h.
2. We observed a reasonable correlation between the severity of precipitation and INP concentrations in our precipitation samples.
3. Seasonal variation of INP concentrations exists - decrease in n_{INP} in winter and spring months. There may be a correlation between local PMs and INPs (to be looked into).
4. Bacteria composition in severe storms is unique and similar to that observed at the local animal feeding facility, but it is not certain what species are ice nucleation active. More detailed biological analyses (incl. Fungi etc.) have been underway.
5. Organic composition is predominant in precipitation residuals (>70%, not shown here), which is similar to the composition of local animal feeding dust (Hiranuma *et al.*, 2011).
6. The presence of high *T* INP and associated hump shape of n_{INP} spectra have been similarly observed for the local animal feeding dust INPs (Whiteside *et al.*, 2018), suggesting a local aerosol-cloud interaction as well as a regional hydrologic cycle.
7. Our findings also suggest that removing INPs from cloud may reduce the intensity of hailstorm and thunderstorm in West Texas.

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