

Ice-nucleating particles impact the severity of precipitations in West Texas

Hemant S. K. Vepuri^{1,*}, Cheyanne A. Rodriguez¹, Dimitri G. Georgakopoulos⁴, Dustin Hume², James Webb², Greg D. Mayer³, and Naruki Hiranuma^{1,*}

5

¹Department of Life, Earth and Environmental Sciences, West Texas A&M University, Canyon, TX, USA

²Office of Information Technology, West Texas A&M University, Canyon, TX, USA

³Department of Environmental Toxicology, Texas Tech University, Lubbock, TX, USA

⁴Department of Crop Science, Agricultural University of Athens, Athens, Greece

10

*Corresponding authors: hsvepuri1@buffs.wtamu.edu and nhiranuma@wtamu.edu

Supplemental Information

15 S1. Precipitation and Particulate Matter Properties

S1.1 Precipitation Categorization

In this study, we have segregated our precipitation samples into four different categories, such as (1) snows, (2) hails/thunderstorms, (3) long-lasting rains, and (4) weak rains. For this categorization, we have considered both our observation-based as well as the disdrometer-assigned National Weather Service (NWS) code. Initially, the precipitation samples had been assigned one of the four categories based on our manual observation. In the next step, we have used each NWS code and its occurrence in each precipitation sample to finalize the precipitation category. During this step, a precipitation sample was categorized into snow, only when we identified a snow type NWS code (Snow: S-, S, S+ and/or Snow Grains: SG). Likewise, a precipitation sample was categorized into hail/thunderstorm, only when the cumulative sum of NWS codes for hail was counted more than five times (i.e., $A + SP \geq 5$; where A and SP are the codes for soft hail and hail, respectively). This limit of five was chosen arbitrarily. If there existed no snow and/or hail type NWS codes, we defined the category as we observed, thus falling in either long-lasting or weak rain category. Overall, in this study we acquired 6 snow, 18 hail/thunderstorm, 13 long-lasting, and 5 weak rain samples for the sampling period of June 2018 – July 2019.

30 Table S1-1 gives the detailed information about the collected precipitation samples. The ID # column goes from 1-42. The column of 'Sample#' is the precipitation sample number in the chronological order. The missing precipitation sample numbers are the ones collected negligible amount of precipitation (typically < 1 ml). This amount is too small to carry out the West Texas Cryogenic Refrigerator Applied to Freezing Test (WT-CRAFT) ice-nucleating particle (INP) measurements. The amount of precipitation collected (in ml) is presented in Table S1-1. Table S1-1 also includes the season
35 in which each precipitation was observed and collected.

S1.2 Disdrometer and IoT Measurements

40 We have measured the ambient meteorological properties, particulate matter (PM)
concentrations and precipitation properties including the intensity and number of precipitation
particles using OTT Parsivel² Laser disdrometer and Internet of Things (IoT) PM sensors. The average
temperature (T), relative humidity, PM concentrations, and intensity measured during each
precipitation event are shown in Table S1-2. The overall average values calculated for the entire
45 sampling period (i.e., June 2018 – July 2019) for T , relative humidity, and PM concentrations are 17.7 ± 15 °C, 46.5 ± 12.3 %, and $3.9 \pm 0.1 \mu\text{g m}^{-3}$ (PM_{1.0}), $4 \pm 0.1 \mu\text{g m}^{-3}$ (PM_{2.5}), and $10.2 \pm 0.2 \mu\text{g m}^{-3}$ (PM₁₀).
The maximum and minimum intensities observed during each precipitation sampling are also shown
in Table S1-2. The cumulative number of detected particles is the total number of precipitation
particles measured by disdrometer in each precipitation sample. Table S1-3 shows the average,
50 maximum and minimum intensity (mm hr^{-1}), number of detected particles, and mode and maximum
hydrometeor size in diameter (mm) for each precipitation category.

Table S1-1. Summary of the Precipitation Categories and sampling periods.

ID#	Sample#	Start Date (Local Time)	End Date (Local Time)	Season	Volume Collected (ml)	NWS Code*	Precipitation Type
1	PCPT_NSB_1	6/12/2018 0:30	6/13/2018 9:30		13	C, R-, SP, R, R+, A	Hail/Thunderstorm
2	PCPT_NSB_2	6/13/2018 10:42	6/17/2018 13:50		15	C, R, R-, R+, A, SP, RL-	Hail/Thunderstorm
3	PCPT_NSB_5	6/30/2018 12:35	7/3/2018 9:35		3	C, R-, R, R+, A, RL-, L-	Long-Lasted Rain
4	PCPT_NSB_6	7/3/2018 9:40	7/6/2018 19:40		3	C, R-, R, A, R+, RL-	Long-Lasted Rain
5	PCPT_NSB_7	7/13/2018 16:40	7/14/2018 8:05		5.1	C, R, R+, A, R-, RL-, SP	Hail/Thunderstorm
6	PCPT_NSB_8	7/14/2018 8:10	7/16/2018 13:20	May-Aug	20	C, R, R-, R+, A, RL-	Hail/Thunderstorm
7	PCPT_NSB_9	7/16/2018 13:30	7/17/2018 18:25		3.5	C, R-, R, R+, A, SP, RL-	Long-Lasted Rain
8	PCPT_NSB_10	7/25/2018 0:30	7/26/2018 10:50		5	C, R-, R, R+, RL-	Long-Lasted Rain
9	PCPT_NSB_11	7/26/2018 11:00	7/30/2018 5:09		1	C, R-, R, R+, RL-	Weak Rain
10	PCPT_NSB_15	8/14/2018 8:20	8/16/2018 18:40		5	C, R-, R, R+, A, SP	Hail/Thunderstorm
11	PCPT_NSB_16	8/16/2018 18:50	8/17/2018 8:20		10	C, R-, R, R+, A, RL-	Hail/Thunderstorm
12	PCPT_NSB_17	8/17/2018 8:30	8/20/2018 8:00		15	C, R-, R, R+, RL+, RL-, L-, A	Long-Lasted Rain
13	PCPT_NSB_19	9/2/2018 12:00	9/5/2018 12:00		1	C, R-, RL-, R	Weak Rain
14	PCPT_NSB_20	9/10/2018 8:10	9/21/2018 12:30		4	C, R-, R, SP, RL-	Long-Lasted Rain
15	PCPT_NSB_23	10/5/2018 0:30	10/6/2018 10:00	Sep-Oct	8	C, SP, A, R+, R, R-, RL-, L-	Hail/Thunderstorm
16	PCPT_NSB_24	10/6/2018 10:10	10/14/2018 10:30		34	C, R-, R, R+, RL-, L-, A, SP, L+	Hail/Thunderstorm
17	PCPT_NSB_25	10/14/2018 10:35	10/21/2018 13:30		8	C, RL-, S-, S, SP, L-, R, R+, RL+	Snow Sample
18	PCPT_NSB_26	10/21/2018 13:35	10/28/2018 16:45		2.5	C, R-, RL-, R, R+, SP, L-	Long-Lasted Rain
19	PCPT_NSB_27	11/5/2018 8:00	11/21/2018 13:55		7	C, RL-, R-, L-, SP, S-, S+, S	Snow Sample
20	PCPT_NSB_29	12/14/2018 15:26	12/26/2018 12:40		3.5	C, RL-, L-, R-, R, R+, SP	Long-Lasted Rain
21	PCPT_NSB_30	12/26/2018 12:50	12/27/2018 21:50	Nov-Jan	3.5	C, R-, RL-, L-, SP, RLS-, S-, S, S+	Snow Sample
22	PCPT_NSB_31	12/27/2018 10:00	12/28/2018 13:45		1.5	C, SP, S-, RL-, S, S+, R-	Snow Sample
23	PCPT_NSB_32	12/28/2018 13:55	12/29/2018 14:08		1	C, S-, SP, L-	Snow Sample
24	PCPT_NSB_43	2/21/2019 18:30	2/23/2019 10:45		2.5	C, R-, R, RL-, R+, A, RLS-, L-	Snow Sample
25	PCPT_NSB_46	3/11/2019 18:00	3/12/2019 9:45		1.5	C, RL-, R-, L-, R, R+	Weak Rain
26	PCPT_NSB_47	3/12/2019 9:50	3/12/2019 18:15		5	C, R-, RL-, R, R+, A, L-	Weak Rain
27	PCPT_NSB_48	3/12/2019 18:20	3/13/2019 10:00	Feb-Apr	12.2	C, L-, RL-, R-, R, R+, SP	Hail/Thunderstorm
28	PCPT_NSB_49	3/19/2019 18:38	3/20/2019 8:50		5	C, R-, RL-, R, A, R+	Long-Lasted Rain
29	PCPT_NSB_51	4/17/2019 12:40	4/18/2019 10:10		7.4	C, R-, R, SP, R+, RL-	Hail/Thunderstorm
30	PCPT_NSB_52	4/22/2019 17:25	4/23/2019 10:10		7.3	C, R-, RL-, R, L-, R+	Long-Lasted Rain
31	PCPT_NSB_54	4/28/2019 10:30	4/30/2019 18:45		2.1	C, RL-, R-, L-, R, SP, A, R+	Long-Lasted Rain
32	PCPT_NSB_55	4/30/2019 18:50	5/3/2019 14:35		1.8	C, L-, RL-, R-, R, R+	Weak Rain
33	PCPT_NSB_56	5/3/2019 14:40	5/20/2019 8:40		6.2	C, L-, R-, R, R+, RL-, SP, A, RLS-	Hail/Thunderstorm
34	PCPT_NSB_57	5/23/2019 9:00	5/26/2019 14:30		3.4	C, R, R-, RL-, A, SP, R+, RL+, L-	Hail/Thunderstorm
35	PCPT_NSB_58	5/26/2019 14:20	5/27/2019 11:35		7.4	C, R-, R, RL-, R+, A, SP, L-	Hail/Thunderstorm
36	PCPT_NSB_59	5/27/2019 11:40	6/1/2019 12:30		7.5	C, R-, R, A, R+, RL-, L-	Long-Lasted Rain
37	PCPT_NSB_60	6/1/2019 12:35	6/2/2019 12:20	May-Aug	17.5	C, R-, RL-, R, R+, A, SP, L-	Hail/Thunderstorm
38	PCPT_NSB_61	6/2/2019 12:25	6/4/2019 11:50		3	C, R-, RL-, R, R+	Long-Lasted Rain
39	PCPT_NSB_62	6/4/2019 12:00	6/8/2019 11:40		3	C, R-, RL-, R, R+, SP, L-	Hail/Thunderstorm
40	PCPT_NSB_63	6/8/2019 11:50	6/14/2019 11:50		7.2	C, RL-, L-, R-, SP, R, R+, A	Hail/Thunderstorm
41	PCPT_NSB_65	6/16/2019 12:15	6/19/2019 12:45		5	C, R-, SP, RL-, R, L-, R+, A	Hail/Thunderstorm
42	PCPT_NSB_66	7/5/2019 19:40	7/6/2019 15:30		25	C, R-, R, R+, SP, A, RL-	Hail/Thunderstorm

*The NWS Code column in the above table shows the assigned precipitation code to each event. The codes are defined as C: no rain; RL, RL+, RL-, L, L+, L-: drizzle; R, R+, R-: rain; A, SP: hail and/or soft hail; and S, S+, S-, RLS: snow and/or snow with rain.

55

60

Table S1-2. Summary of the Precipitation properties and meteorological parameters during the sampling.

ID#	Sample#	Precipitation Type	Average T (°C) ± standard dev.	Average RH (%) ± standard dev.	Cumulative No. of detected particles	Average Intensity (mm hr ⁻¹) ± standard error	Maximum Intensity (mm hr ⁻¹)	Minimum Intensity (mm hr ⁻¹)	Average PM _{1.0} (µg m ⁻³) ± standard error	Average PM _{2.5} (µg m ⁻³) ± standard error	Average PM ₁₀ (µg m ⁻³) ± standard error	
17	PCPT_NSB_25	Snow	8.55 ± 8.62	51.94 ± 11.49	2.49E+05	1.00 ± 0.04	21.47	0.01	0.57 ± 0.11	1.54 ± 0.11	4.01 ± 0.50	
19	PCPT_NSB_27		4.26 ± 10.33	41.00 ± 3.38	6.58E+05	2.96 ± 0.10	26.68	0.01	1.53 ± 0.14	0.20 ± 0.02	3.79 ± 0.27	
21	PCPT_NSB_30		2.53 ± 5.92	54.56 ± 10.30	1.68E+05	1.16 ± 0.06	14.21	0.02	4.23 ± 1.04	2.34 ± 0.59	11.36 ± 1.91	
22	PCPT_NSB_31		-3.09 ± 4.83	47.35 ± 5.03	7.25E+04	1.03 ± 0.06	7.42	0.14	—	0.51 ± 0.07	—	
23	PCPT_NSB_32		-6.50 ± 6.70	53.83 ± 6.24	1.07E+04	0.33 ± 0.01	1.12	0.01	0.06 ± 0.05	3.61 ± 0.32	—	
24	PCPT_NSB_43		2.40 ± 5.23	56.00 ± 8.78	4.16E+04	1.12 ± 0.11	22.58	0.05	1.76 ± 0.35	3.70 ± 0.57	7.99 ± 0.93	
1	PCPT_NSB_1	Hail/Thunderstorm	29.76 ± 12.94	46.70 ± 11.90	2.76E+04	11.08 ± 0.94	67.33	0.05	2.70 ± 0.31	4.09 ± 0.31	7.13 ± 0.58	
2	PCPT_NSB_2		29.61 ± 8.79	46.92 ± 12.37	8.48E+04	5.97 ± 0.57	83.89	0.03	0.90 ± 0.10	1.51 ± 0.11	3.33 ± 0.21	
5	PCPT_NSB_7		21.57 ± 3.87	58.81 ± 9.28	1.53E+04	3.95 ± 0.49	40.27	0.03	0.19 ± 0.10	1.25 ± 0.34	2.62 ± 0.45	
6	PCPT_NSB_8		32.41 ± 11.19	—	7.7E+04	8.60 ± 0.66	105.53	0.04	—	—	—	
10	PCPT_NSB_15		31.90 ± 11.60	53.34 ± 12.37	3.33E+04	3.69 ± 0.37	85.30	0.04	7.62 ± 1.39	7.80 ± 0.55	15.63 ± 2.39	
11	PCPT_NSB_16		25.47 ± 6.30	52.69 ± 5.75	4.75E+04	5.52 ± 0.65	90.45	0.03	4.30 ± 0.38	5.95 ± 0.38	10.21 ± 0.69	
15	PCPT_NSB_23		21.76 ± 10.88	58.87 ± 10.50	2.9E+04	11.63 ± 1.51	80.67	0.02	4.09 ± 0.69	5.47 ± 0.67	10.35 ± 1.26	
16	PCPT_NSB_24		11.72 ± 6.31	66.17 ± 7.63	3.49E+05	2.88 ± 0.17	110.49	0.01	3.41 ± 0.35	4.01 ± 0.38	10.51 ± 1.15	
27	PCPT_NSB_48		7.00 ± 2.91	66.16 ± 9.43	7.63E+04	2.67 ± 0.12	19.90	0.01	0.78 ± 0.21	2.05 ± 0.55	3.80 ± 0.65	
29	PCPT_NSB_51		12.12 ± 9.11	57.10 ± 10.60	3.83E+04	2.23 ± 0.08	9.64	0.04	—	1.47 ± 0.34	—	
33	PCPT_NSB_56		20.03 ± 11.31	51.37 ± 13.12	1.96E+05	2.47 ± 0.12	83.20	0.01	—	3.75 ± 0.20	—	
34	PCPT_NSB_57		21.62 ± 8.19	63.98 ± 8.39	1.37E+04	3.33 ± 0.54	65.64	0.02	10.53 ± 0.64	11.40 ± 0.42	21.70 ± 1.12	
35	PCPT_NSB_58		21.51 ± 7.01	68.47 ± 8.03	3.29E+04	6.56 ± 0.98	103.17	0.02	10.85 ± 0.69	12.28 ± 0.74	22.22 ± 1.30	
37	PCPT_NSB_60		23.57 ± 11.35	57.97 ± 11.33	8.88E+04	5.69 ± 0.34	56.77	0.01	2.86 ± 0.54	4.28 ± 0.48	7.03 ± 0.86	
39	PCPT_NSB_62		25.48 ± 10.80	56.46 ± 10.06	3.52E+04	1.33 ± 0.10	25.75	0.02	1.97 ± 0.33	2.28 ± 0.28	5.31 ± 0.60	
40	PCPT_NSB_63		24.20 ± 10.62	47.64 ± 11.15	2.43E+04	6.93 ± 1.50	129.25	0.01	1.63 ± 0.23	1.95 ± 0.18	5.61 ± 0.60	
41	PCPT_NSB_65		27.02 ± 10.82	52.40 ± 11.07	2.05E+04	3.34 ± 0.40	60.46	0.01	2.08 ± 0.27	2.75 ± 0.28	6.03 ± 0.50	
42	PCPT_NSB_66		22.50 ± 6.03	58.59 ± 8.88	9.48E+04	7.00 ± 0.34	88.18	0.04	1.93 ± 0.40	3.76 ± 0.47	5.74 ± 0.75	
3	PCPT_NSB_5		Long-Lasted Rain	30.67 ± 9.62	46.25 ± 10.57	1.16E+04	3.72 ± 0.54	34.77	0.04	2.07 ± 0.21	3.00 ± 0.22	6.59 ± 0.65
4	PCPT_NSB_6			33.69 ± 9.60	42.19 ± 9.94	1.35E+04	10.51 ± 1.20	40.76	0.07	2.13 ± 0.17	3.21 ± 0.19	6.03 ± 0.30
7	PCPT_NSB_9	34.89 ± 12.21		30.76 ± 0.74	1.67E+04	5.77 ± 0.64	34.37	0.04	1.44 ± 0.19	2.58 ± 0.22	5.53 ± 0.37	
8	PCPT_NSB_10	30.23 ± 10.32		44.30 ± 11.62	5.23E+04	3.06 ± 0.14	13.06	0.04	6.17 ± 0.27	8.14 ± 0.33	12.61 ± 0.52	
12	PCPT_NSB_17	28.71 ± 10.98		52.15 ± 9.98	7.14E+04	7.85 ± 0.66	74.67	0.03	6.14 ± 0.68	7.50 ± 0.72	13.49 ± 1.32	
14	PCPT_NSB_20	26.51 ± 9.01		54.43 ± 10.91	2.77E+04	0.96 ± 0.06	6.85	0.02	3.61 ± 0.22	4.50 ± 0.20	9.23 ± 0.44	
18	PCPT_NSB_26	14.81 ± 10.75		51.91 ± 11.22	2.04E+05	0.89 ± 0.03	12.64	0.02	1.67 ± 0.22	2.86 ± 0.28	5.81 ± 0.57	
20	PCPT_NSB_29	5.94 ± 8.97		41.51 ± 11.64	2.07E+04	1.74 ± 0.21	28.48	0.01	2.34 ± 0.26	2.89 ± 0.25	8.82 ± 0.66	
28	PCPT_NSB_49	4.42 ± 2.28		57.95 ± 5.32	7.69E+04	1.13 ± 0.05	12.65	0.02	—	9.58 ± 0.91	—	
30	PCPT_NSB_52	9.57 ± 1.66		65.47 ± 4.02	1.26E+05	1.17 ± 0.05	9.23	0.01	—	10.09 ± 1.77	—	
31	PCPT_NSB_54	18.32 ± 10.31		52.92 ± 11.46	2.42E+04	1.19 ± 0.32	86.29	0.01	—	5.03 ± 0.49	—	
36	PCPT_NSB_59	24.66 ± 11.30		48.02 ± 14.00	6.3E+04	3.35 ± 0.28	69.13	0.02	5.51 ± 0.58	3.30 ± 0.42	12.40 ± 1.15	
38	PCPT_NSB_61	26.91 ± 8.74		57.18 ± 9.31	2.02E+04	2.83 ± 0.21	19.25	0.03	1.30 ± 0.20	2.38 ± 0.21	4.11 ± 0.38	
9	PCPT_NSB_11	Weak Rain		31.21 ± 10.43	48.01 ± 10.87	1.27E+04	2.12 ± 0.21	9.09	0.03	8.02 ± 0.68	9.03 ± 0.37	15.60 ± 1.13
13	PCPT_NSB_19		27.99 ± 9.41	51.91 ± 11.35	1.04E+04	1.05 ± 0.07	4.01	0.03	1.99 ± 0.36	2.72 ± 0.30	6.12 ± 0.79	
25	PCPT_NSB_46		3.54 ± 0.77	68.65 ± 1.14	1.15E+04	2.17 ± 0.45	31.44	0.03	1.70 ± 0.49	2.93 ± 0.62	7.82 ± 0.99	
26	PCPT_NSB_47		8.86 ± 2.91	70.68 ± 2.29	3.9E+04	2.05 ± 0.37	83.67	0.01	—	0.85 ± 0.36	—	
32	PCPT_NSB_55		16.14 ± 10.16	61.02 ± 12.75	1.71E+04	0.21 ± 0.06	15.60	0.01	—	5.61 ± 0.43	—	

65 Table S1-3. Summary of the Precipitation Intensity and Particles Size.

Precipitation Type	Precipitation Properties							
	Average Intensity (mm hr ⁻¹) ± standard error	Maximum Intensity (mm hr ⁻¹)	Minimum Intensity (mm hr ⁻¹)	Average No. of detected precipitation particles ± standard error	Maximum No. of detected precipitation particles	Minimum No. of detected precipitation particles	Hydrometeor Mode diameter (mm)	Maximum diameter of hydrometeor (mm)
Snow (n=6)	1.27E+00 ± 3.61E-01	26.68	0.01	2E+05 ± 2E+02	6.58E+05	1.07E+04	0.44	17
Hail/Thunderstorm (n=18)	5.27E+00 ± 7.01E-01	129.25	0.01	7.13E+04 ± 1.93E+04	3.49E+05	1.37E+04	0.44	17
Long-Lasted Rain (n=13)	3.4E+00 ± 8.26E-01	86.29	0.01	5.6E+04 ± 1.54E+04	2.04E+05	1.16E+04	0.44	17
Weak Rain (n=5)	1.52E+00 ± 3.86E-01	83.67	0.01	1.81E+04 ± 5.35E+03	3.9E+04	1.04E+04	0.31	5.5

* n is the number of samples in each precipitation category.

70

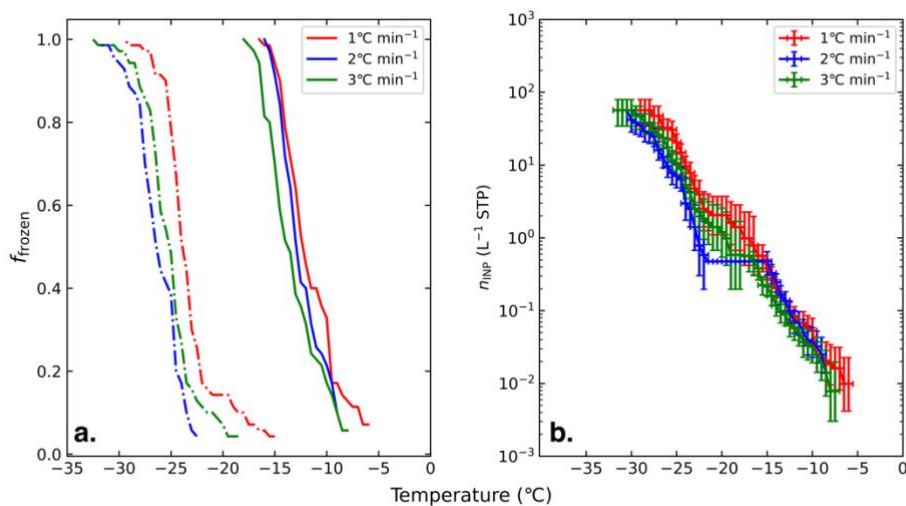
75

S2. Cooling Rate Dependency and Time Trial Test

S2.1. Cooling Rate Dependency Test

80 For this study, we have cooled the super microliter droplets from all our precipitation samples in the WT-CRAFT system at a cooling rate of $1^{\circ}\text{C min}^{-1}$. However, we observe a rapid cooling rate of $2\text{-}3^{\circ}\text{C min}^{-1}$ in the invigorating convective systems like hurricanes and thunderstorms depending on the vertical updrafts in that weather system. This variation in the cooling rate was mimicked at laboratory conditions by conducting our immersion freezing tests at different cooling rates. To understand the effect of different cooling rates on INP
85 measurements, we have selected a hail/thunderstorm sample (ID# 16), which was observed during the landfall of Hurricane Michael in 2018. Figure S2-1 shows the frozen fraction curves and n_{INP} values for this chosen sample at three different cooling rates (i.e., at $1^{\circ}\text{C min}^{-1}$, $2^{\circ}\text{C min}^{-1}$, and $3^{\circ}\text{C min}^{-1}$). Throughout this test, the T discrepancy was within the system's uncertainty (i.e., $\pm 0.5^{\circ}\text{C}$).

90 A slight decrease in freezing activity (within a factor of 2-3) was observed with an increase in cooling rate as shown in Figure S2-1. This negligible variation in the freezing behavior highlights that the sensitivity of freezing to ΔT ($^{\circ}\text{C}$) is much higher compared to Δt (min), supporting previous simulation studies (Ervens and Feingold, 2013). This result also supports our assumption for this study, that freezing activity is independent of time following the singular freezing theory (Niedermeier et al., 2011).



110 **Figure S2-1.** The cooling rate dependency tests for a hail/thunderstorm sample (ID# 16) showing (a) frozen fraction curves, the dash-dot curves are for a serial dilution fold of 100 and (b) n_{INP} curves. The X-axis error bars represent constant uncertainty of $\pm 0.5^{\circ}\text{C}$ in temperature. The Y-axis error bars show 95% confidence interval for n_{INP} shown only for one test
115 here.

S2.2. Time Trial Test

There was a time gap between our sample collection day and the day of droplet freezing assay measurements. The effect of this delay in measurements on immersion freezing propensity was examined by systematically carrying out time trial tests on a hail/thunderstorm sample (ID# 16). Initially the samples were stored at 4°C in the refrigerator since the day of sample collection to until droplet freezing assay measurements. Multiple immersion freezing experiments were carried out for the same sample every two weeks since the first droplet freezing assay measurement. Overall, three time trial tests were conducted on hail/thunderstorm sample (ID# 16) over a period of one month.

We observed a slight decrease in the freezing efficiency with the time (Fig. S2-2), but not more than a factor of 3-4. Similarly, the n_{INP} for the tested hail/thunderstorm sample (ID# 16) shown in Figure S2-2b has less than a factor of 2-3 variation between different time trial experiments. Therefore, these results showed that our immersion freezing measurements were not affected by the delay in droplet freezing assay experiments, agreeing with the previous studies, such as Murray et al. (2012).

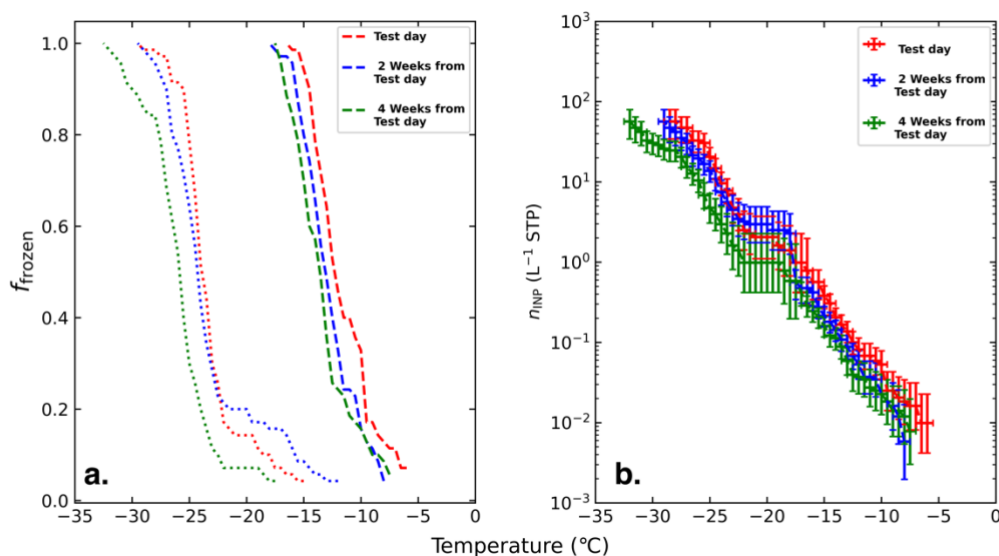


Figure S2-2. The time trial tests for a hail/thunderstorm sample (ID# 16) showing (a) frozen fraction curves, the dotted curves are for a serial dilution fold of 100 and (b) n_{INP} curves. The X-axis error bars represent constant uncertainty of $\pm 0.5^{\circ}\text{C}$ in temperature. The Y-axis error bars show 95% confidence interval for n_{INP} shown only for one test here.

155

160

165

170

175

180

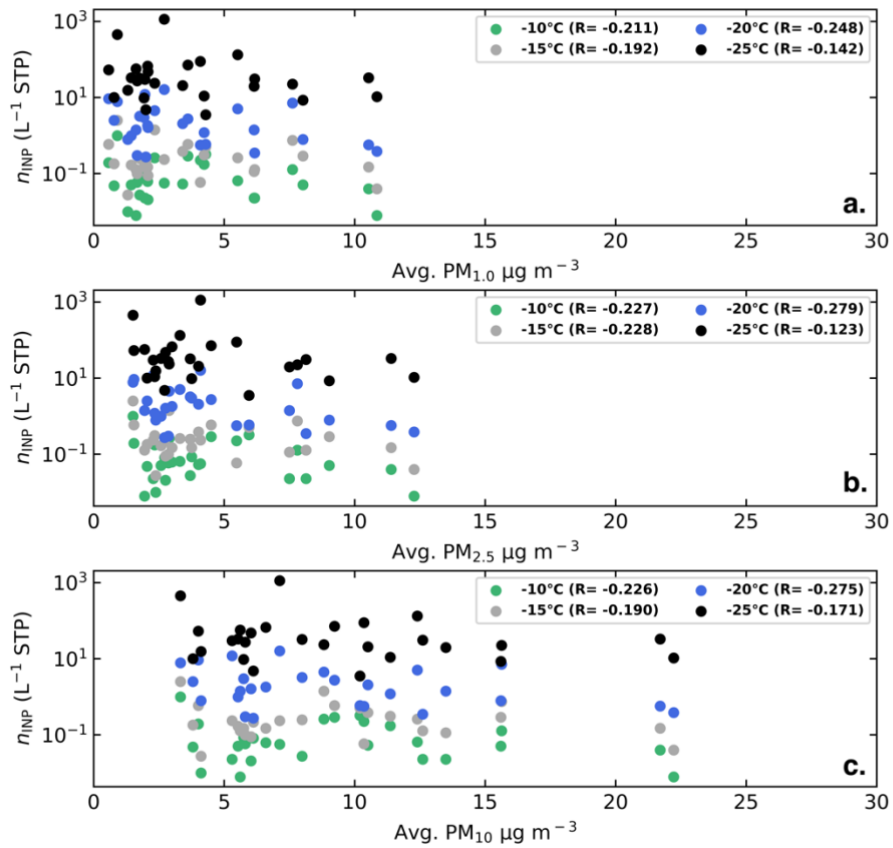


Figure. S3. The comparison of n_{INP} (L^{-1} air) from precipitation samples with (a) $\text{PM}_{1.0}$, (b) $\text{PM}_{2.5}$, and (c) PM_{10} concentrations. 'R' represents the Pearson correlation coefficient (R-value) for PM – INP comparisons at a given temperature.

S3. INP Variation with Precipitation Category

Table S3-1. Summary of precipitation category-wise average and maximum n_{INP} .

Precipitation Type	n_{INP} (L ⁻¹ STP) values									
	$(n_{INP})_{max}$ at -5°C	$(n_{INP})_{max}$ at -10°C	$(n_{INP})_{max}$ at -15°C	$(n_{INP})_{max}$ at -20°C	$(n_{INP})_{max}$ at -25°C	Average $n_{INP} \pm$ standard error at -5°C	Average $n_{INP} \pm$ standard error at -10°C	Average $n_{INP} \pm$ standard error at -15°C	Average $n_{INP} \pm$ standard error at -20°C	Average $n_{INP} \pm$ standard error at -25°C
Snow *(n=6)	3.46E-02	1.62E+00	2.98E+00	1.62E+01	5.31E+01	2.76E-02 ± 7.02E-03	4.22E-01 ± 3.01E-01	8.28E-01 ± 5.44E-01	5.74E+00 ± 2.46E+00	2.71E+01 ± 8.72E+00
Hail/Thunderstorm (n=18)	1.13E-01	9.88E-01	2.51E+00	1.61E+01	1.13E+03	1.03E-01 ± 1.03E-02	1.54E-01 ± 5.74E-02	4.8E-01 ± 1.61E-01	4.23E+00 ± 1.25E+00	1.18E+02 ± 6.81E+01
Long-Lasted Rain (n=13)	1.19E-02	2.89E-01	1.4E+00	5.84E+00	1.32E+02	7.88E-03 ± 2.04E-03	8.77E-02 ± 2.63E-02	2.7E-01 ± 1.03E-01	2.02E+00 ± 5.87E-01	3.96E+01 ± 1.04E+01
Weak Rain (n=5)	5.84E-02	6.5E-01	7.85E-01	4.74E+00	2.05E+02	5.84E-02	1.97E-01 ± 1.52E-01	2.66E-01 ± 1.4E-01	1.28E+00 ± 8.72E-01	4.57E+01 ± 3.99E+01

* n is the number of samples in each precipitation category.

Table S4-1. Abundance of major bacterial orders in precipitation samples. Numbers indicate percentage of the OTUs/ASVs for each order in the total bacterial microbiome.

Precipitation Type	Hailstorm			Long-				24-hour dry-	
	Hailstorm	Hailstorm	Hailstorm	Lastest Rain	Feedlot	Feedlot	Feedlot	Feedlot	deposition blank
Taxonomy									
Bacteria; Unclassified	2.6%	0.0%	0.0%	0.0%	0.5%	0.0%	1.3%	0.0%	2.8%
Bacteria; Unclassified	0.0%	0.0%	0.8%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Acidobacteria; Solibacteres; Solibacterales; Bryobacteraceae	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.9%	0.0%	0.0%
Bacteria; Actinobacteria; Actinobacteria; Actinomycetales	0.0%	0.0%	0.0%	0.0%	0.0%	2.4%	0.0%	0.0%	0.0%
Bacteria; Actinobacteria; Actinobacteria; Actinomycetales; Actinosynnemataceae	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	13.4%
Bacteria; Actinobacteria; Actinobacteria; Actinomycetales; Geodermatophilaceae; Blastococcus	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.4%
Bacteria; Actinobacteria; Actinobacteria; Actinomycetales; Microbacteriaceae; Labedella	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.0%
Bacteria; Actinobacteria; Actinobacteria; Actinomycetales; Microbacteriaceae; Leifsonia	0.2%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	4.1%
Bacteria; Actinobacteria; Actinobacteria; Actinomycetales; Micrococccaceae; Arthrobacter	0.0%	0.0%	0.0%	1.6%	0.0%	3.0%	0.0%	0.0%	0.0%
Bacteria; Actinobacteria; Actinobacteria; Actinomycetales; Nocardiaceae	0.0%	0.0%	0.0%	4.6%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Actinobacteria; Actinobacteria; Actinomycetales; Nocardiaceae; Rhodococcus	0.0%	0.0%	0.0%	0.0%	2.1%	1.4%	0.0%	0.0%	0.0%
Bacteria; Actinobacteria; Actinobacteria; Actinomycetales; Nocardioidaceae; Marmoricola	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	8.0%
Bacteria; Actinobacteria; Actinobacteria; Actinomycetales; Nocardioidaceae; Nocardioides	0.0%	0.0%	0.0%	1.1%	3.5%	0.0%	0.1%	0.0%	0.0%
Bacteria; Actinobacteria; Thermoleophyllia; Solirubrobacterales; Patulibacteraceae	0.0%	1.5%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Actinobacteria; Thermoleophyllia; Solirubrobacterales; Patulibacteraceae; Patulibacter	0.6%	0.0%	0.0%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Armatimonadetes	0.0%	0.0%	0.0%	3.2%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Armatimonadetes; Armatimonadia; Armatimonadales; Armatimonadaceae	0.0%	6.5%	0.0%	3.9%	0.0%	0.0%	0.0%	6.0%	0.0%
Bacteria; Armatimonadetes; Armatimonadia; Armatimonadales; Armatimonadaceae	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Armatimonadetes; Fimbriimonadia; Fimbriimonadales; Fimbriimonadaceae; Fimbriimonas	0.0%	0.0%	0.0%	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Bacteroidetes	0.0%	0.0%	0.0%	3.2%	1.0%	0.0%	13.7%	0.0%	0.0%
Bacteria; Bacteroidetes; Bacteroidia; Bacteroidales	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%	9.5%	0.0%
Bacteria; Bacteroidetes; Cytophagia; Cytophagales	0.0%	0.8%	0.0%	5.6%	0.0%	0.0%	4.0%	0.0%	0.0%
Bacteria; Bacteroidetes; Cytophagia; Cytophagales; Cyclobacteriaceae	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%	0.0%
Bacteria; Bacteroidetes; Cytophagia; Cytophagales; Cytophagaceae; Hymenobacter	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Bacteroidetes; Cytophagia; Cytophagales; Cytophagaceae; Rhodocytophaga	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.2%
Bacteria; Bacteroidetes; Cytophagia; Cytophagales; Cytophagaceae; Rudanella	0.0%	1.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Bacteroidetes; Cytophagia; Cytophagales; Cytophagaceae; Spirosoma	2.3%	6.8%	0.0%	3.8%	0.0%	0.0%	0.0%	0.0%	5.6%
Bacteria; Bacteroidetes; Cytophagia; Cytophagales; Cytophagaceae; Sporocytophaga	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%	0.0%
Bacteria; Bacteroidetes; Cytophagia; Cytophagales; Flammeovirgaceae	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%
Bacteria; Bacteroidetes; Cytophagia; Cytophagales; Flammeovirgaceae; Marinoscillum	8.7%	3.2%	17.3%	8.5%	8.4%	3.0%	6.2%	5.5%	0.0%
Bacteria; Bacteroidetes; Flavobacteriia; Flavobacteriales; Flavobacteriaceae	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	5.5%	0.0%	0.0%
Bacteria; Bacteroidetes; Flavobacteriia; Flavobacteriales; Flavobacteriaceae; Flavobacterium	0.0%	0.0%	4.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Bacteroidetes; Flavobacteriia; Flavobacteriales; Flavobacteriaceae; Persicivirga	0.0%	0.0%	0.0%	0.0%	6.8%	0.0%	2.1%	0.0%	0.0%
Bacteria; Bacteroidetes; Flavobacteriia; Flavobacteriales; Weeksellaceae	0.0%	0.0%	0.0%	0.0%	0.0%	2.2%	0.0%	0.0%	0.0%
Bacteria; Bacteroidetes; Flavobacteriia; Flavobacteriales; Weeksellaceae; Elizabethkingia	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.1%	0.0%	0.0%
Bacteria; Bacteroidetes; Sphingobacteriia; Sphingobacteriales; Sphingobacteriaceae; Mucilaginibacter	0.0%	0.0%	5.8%	0.0%	0.0%	0.0%	3.6%	0.0%	0.0%
Bacteria; Bacteroidetes; Sphingobacteriia; Sphingobacteriales; Sphingobacteriaceae; Pedobacter	3.2%	0.0%	1.8%	5.3%	1.0%	0.0%	6.6%	0.0%	0.0%
Bacteria; Bacteroidetes; Saprospirae; Saprospirales; Chitinophagaceae	0.0%	0.0%	0.0%	1.6%	0.0%	0.0%	1.1%	9.7%	1.1%
Bacteria; Bacteroidetes; Saprospirae; Saprospirales; Chitinophagaceae; Ferruginibacter	0.0%	0.0%	0.0%	0.0%	5.3%	0.0%	0.0%	0.0%	0.0%

Table S4-1. Abundance of major bacterial orders in precipitation samples. Numbers indicate percentage of the OTUs/ASVs for each order in the total bacterial microbiome – continued.

Precipitation Type	Hailstorm	Hailstorm	Hailstorm	Long-					24-hour dry- deposition blank
				Lasted Rain	Feedlot	Feedlot	Feedlot	Feedlot	
Taxonomy									
Bacteria; Bacteroidetes; Saprospirae; Saprospirales; Chitinophagaceae; Filimonas	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.5%	0.0%	0.0%
Bacteria; Bacteroidetes; Saprospirae; Saprospirales; Chitinophagaceae; Parasegitibacter	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.8%	0.0%	0.0%
Bacteria; Bacteroidetes; Saprospirae; Saprospirales; Chitinophagaceae; Trachelomonas	3.9%	0.0%	0.0%	9.5%	0.0%	0.0%	0.0%	0.0%	8.2%
Bacteria; Chlorobi	2.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Cyanobacteria	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%
Bacteria; FBP	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Firmicutes; Bacilli; Bacillales	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.0%	0.0%	0.0%
Bacteria; Firmicutes; Bacilli; Bacillales; Bacillaceae	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%	1.1%	0.0%	0.0%
Bacteria; Firmicutes; Bacilli; Bacillales; Bacillaceae; Bacillus	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.8%	0.0%	0.0%
Bacteria; Firmicutes; Bacilli; Bacillales; Planococcaceae	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.2%	0.0%	0.0%
Bacteria; Firmicutes; Bacilli; Lactobacillales; Aerococcaceae; Lacticigenium	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%
Bacteria; Firmicutes; Clostridia; Clostridiales; Clostridiaceae; Clostridium	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%	0.7%	0.0%	0.0%
Bacteria; Gemmatimonadetes; Gemm-3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%
Bacteria; Gemmatimonadetes; Gemmatimonadetes; Gemmatimonadales	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.8%
Bacteria; Gemmatimonadetes; Gemmatimonadetes; Gemmatimonadales; Ellin5301	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Gemmatimonadetes; Gemmatimonadetes; Gemmatimonadales; Gemmatimonadaceae; Gemmatimonas	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Bacteria; Planctomycetes; Phycisphaerae	3.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Planctomycetes; Planctomycetia; Gemmatales; Isosphaeraceae	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Planctomycetes; Planctomycetia; Gemmatales; Isosphaeraceae; Nostocoida	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.8%
Bacteria; Proteobacteria	8.3%	8.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Proteobacteria; Alphaproteobacteria	0.0%	0.0%	0.0%	0.0%	1.5%	0.0%	3.1%	17.7%	0.0%
Bacteria; Proteobacteria; Alphaproteobacteria; Caulobacterales; Caulobacteraceae	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.6%
Bacteria; Proteobacteria; Alphaproteobacteria; Caulobacterales; Caulobacteraceae; Arthrospira	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.4%	0.0%	0.0%
Bacteria; Proteobacteria; Alphaproteobacteria; Caulobacterales; Caulobacteraceae; Brevundimonas	6.2%	15.0%	0.0%	0.0%	1.2%	0.0%	4.5%	19.7%	2.8%
Bacteria; Proteobacteria; Alphaproteobacteria; Caulobacterales; Caulobacteraceae; Caulobacter	2.5%	2.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Proteobacteria; Alphaproteobacteria; Rhizobiales	2.8%	0.0%	0.0%	5.3%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Proteobacteria; Alphaproteobacteria; Rhizobiales; Aurantimonadaceae; Aurantimonas	0.0%	0.8%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Proteobacteria; Alphaproteobacteria; Rhizobiales; Beijerinckiaceae	0.0%	0.0%	0.0%	3.5%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Proteobacteria; Alphaproteobacteria; Rhizobiales; Bradyrhizobiaceae	1.8%	2.4%	0.0%	3.5%	0.0%	0.0%	0.0%	0.0%	0.3%
Bacteria; Proteobacteria; Alphaproteobacteria; Rhizobiales; Phyllobacteriaceae	0.0%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Proteobacteria; Alphaproteobacteria; Rhizobiales; Rhizobiaceae; Rhizobium	3.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Proteobacteria; Alphaproteobacteria; Rhizobiales; Xanthobacteraceae	0.0%	1.6%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Proteobacteria; Alphaproteobacteria; Rhizobiales; Xanthobacteraceae; Ancylobacter	0.0%	0.0%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Proteobacteria; Alphaproteobacteria; Rhodobacterales; Rhodobacteraceae	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Proteobacteria; Alphaproteobacteria; Rhodospirillales; Acetobacteraceae	1.8%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%
Bacteria; Proteobacteria; Alphaproteobacteria; Rhodospirillales; Acetobacteraceae; Roseomonas	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	0.1%	0.0%	0.0%
Bacteria; Proteobacteria; Alphaproteobacteria; Sphingomonadales	3.5%	5.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table S4-1. Abundance of major bacterial orders in precipitation samples. Numbers indicate percentage of the OTUs/ASVs for each order in the total bacterial microbiome – continued.

Precipitation Type	Hailstorm	Hailstorm	Hailstorm	Long-	Feedlot	Feedlot	Feedlot	Feedlot	24-hour dry-
				Lasted				deposition	
Taxonomy	Rain								
									blank
Bacteria; Proteobacteria; Alphaproteobacteria; Sphingomonadales; Erythrobacteraceae	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.7%
Bacteria; Proteobacteria; Alphaproteobacteria; Sphingomonadales; Erythrobacteraceae; Porphyrobacter	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%
Bacteria; Proteobacteria; Alphaproteobacteria; Sphingomonadales; Sphingomonadaceae	0.0%	4.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.5%
Bacteria; Proteobacteria; Alphaproteobacteria; Sphingomonadales; Sphingomonadaceae; Novosphingobium	4.2%	0.0%	5.1%	0.0%	0.0%	0.0%	0.5%	8.3%	0.0%
Bacteria; Proteobacteria; Alphaproteobacteria; Sphingomonadales; Sphingomonadaceae; Sphingomonas	0.7%	14.1%	7.4%	0.7%	0.0%	1.4%	0.0%	0.0%	2.1%
Bacteria; Proteobacteria; Betaproteobacteria; Burkholderiales; Comamonadaceae	8.8%	0.0%	5.9%	4.3%	0.0%	0.0%	0.3%	0.0%	5.9%
Bacteria; Proteobacteria; Betaproteobacteria; Burkholderiales; Comamonadaceae; Acidovorax	0.0%	0.0%	3.9%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%
Bacteria; Proteobacteria; Betaproteobacteria; Burkholderiales; Comamonadaceae; Pseudorhodofera	0.0%	3.7%	0.0%	0.0%	7.4%	0.0%	0.0%	0.0%	0.0%
Bacteria; Proteobacteria; Betaproteobacteria; Burkholderiales; Oxalobacteraceae	4.1%	6.1%	19.4%	0.0%	6.7%	14.6%	0.0%	5.2%	0.0%
Bacteria; Proteobacteria; Betaproteobacteria; Burkholderiales; Oxalobacteraceae; Herminiimonas	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.4%	0.0%	0.0%
Bacteria; Proteobacteria; Betaproteobacteria; Burkholderiales; Oxalobacteraceae; Massilia	13.9%	10.6%	8.4%	11.3%	53.9%	65.4%	6.5%	10.6%	0.9%
Bacteria; Proteobacteria; Betaproteobacteria; Burkholderiales; Oxalobacteraceae; Naxibacter	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%	0.0%	0.0%
Bacteria; Proteobacteria; Deltaproteobacteria; Myxococcales	0.0%	0.0%	0.0%	2.3%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Proteobacteria; Deltaproteobacteria; Myxococcales; OM27	5.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Proteobacteria; Deltaproteobacteria; Myxococcales; Polyangiaceae	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%
Bacteria; Proteobacteria; Gammaproteobacteria; Alteromonadales; Alteromonadaceae; Gilvimirinus	0.0%	0.0%	11.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Proteobacteria; Gammaproteobacteria; Alteromonadales; OM60; Halia	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%
Bacteria; Proteobacteria; Gammaproteobacteria; Enterobacteriales; Enterobacteriaceae; Pseudomonas	0.0%	0.0%	6.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Proteobacteria; Gammaproteobacteria; Legionellales	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bacteria; Proteobacteria; Gammaproteobacteria; Pseudomonadales; Moraxellaceae; Acinetobacter	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%	0.4%	0.0%	0.0%
Bacteria; Proteobacteria; Gammaproteobacteria; Pseudomonadales; Pseudomonadaceae; Pseudomonas	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%
Bacteria; Proteobacteria; Gammaproteobacteria; Xanthomonadales; Xanthomonadaceae; Achromobacter	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
Bacteria; Proteobacteria; Gammaproteobacteria; Xanthomonadales; Xanthomonadaceae; Lysobacter	0.0%	1.8%	0.0%	0.6%	0.0%	0.0%	0.0%	3.8%	0.0%
Bacteria; Thermi; Deinococci; Deinococcales; Deinococcaceae; Deinococcus	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.0%
Bacteria; Verrucomicrobia; Opitutae; Opitiales; Opitutaceae; Opitutus	0.0%	0.0%	0.0%	0.9%	0.0%	0.0%	3.7%	0.0%	0.0%
Bacteria; Verrucomicrobia; Pedosphaerae; Pedosphaerales; Pedosphaeraceae	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.5%	0.0%	0.0%
Bacteria; Verrucomicrobia; Spartobacteria; Chthoniobacteriales; Chthoniobacteraceae	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%	0.0%
Bacteria; Verrucomicrobia; Spartobacteria; Chthoniobacteriales; Chthoniobacteraceae; Chthoniobacter	1.7%	0.0%	0.0%	3.8%	0.0%	0.0%	0.0%	0.0%	0.0%

220 SI List of Abbreviations

IoT	Internet of Things
INP	Ice-nucleating Particle
n_{INP}	INP concentration
225 NWS	National Weather Service
PM	Particulate Matter
T	Temperature
ΔT	Temperature gradient
Δt	Time difference
230 WT-CRAFT	West Texas Cryogenic Refrigerator Applied to Freezing Test

Data Availability

Original data created for the study will be available in a persistent repository upon publication within www.wtamu.edu.

235

SI References

Ervens, B., and Feingold, G.: Sensitivities of immersion freezing: Reconciling classical nucleation theory and deterministic expressions, *Geophysical Research Letters*, 40, 3320-3324, 2013.

240

Murray, B. J., O'sullivan, D., Atkinson, J. D., and Webb, M. E.: Ice nucleation by particles immersed in supercooled cloud droplets, *Chem. Soc. Rev.*, 41, 6519-6554, 2012.

245

Niedermeier, D., Shaw, R. A., Hartmann, S., Wex, H., Clauss, T., Voigtländer, J., and Stratmann, F.: Heterogeneous ice nucleation: exploring the transition from stochastic to singular freezing behavior, *Atmos. Chem. Phys.*, 11, 8767-8775, 2011.