Verification of the Origins of Rotation in Tornadoes Experiment-Southeast (VORTEX-SE) Parsivel Disdrometer Data Summary

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1.0 Data Set Overview

1.1 Introduction

The VORTEX-SE (VSE) field project was conducted March 1 to May 1, 2016. During this period, two UAH 2nd generation Parsivel disdrometer were deployed in order to measure the surface raindrop size distribution and provide a reference reflectivity data.

1.2 Time Period Covered by the Data

Data available are for the Pre-VSE IOP on 02/24, the shakedown mission on 03/01 and 03/02 and for the following intensive operation period (IOP) days: 03/14 (IOP1), 03/24 (IOP2), 03/31 and 04/01 (IOP3), 04/27 and 04/28 (IOP4), 04/29 (IOP5), 04/30 (IOP6), 05/01 (IOP7).

1.3 Physical Location

Disdrometers were deployed at the UAH berm site on coordinates 34° 43' 24" N 86° 38' 31" W and elevation of 696 ft or 212 m (NOWCASTR, 2016). One Parsivel (Inside-fence Parsivel, hereafter) was deployed inside a fence to avoid wind effect on drop data, while other Parsivel (Outside-fence Parsivel, hereafter) was deployed outside a fence for reference. Berm site and Parsivel disdrometers are shown on Figure 1.

Figure 1 – Left: Outside-fence Parsivel disdrometer and the fence on the back. Right: Inside-fence Parsivel disdrometer.

2.0 Instrument Description

The OTT PARSIVEL2 (Particle Size and VELocity, 2nd generation) instrument is a laser-based optical system for complete and reliable measurement of all types of precipitation. The size range of measurable liquid precipitation particles is from 0.2 to 5 mm and for solid precipitation particles is from 0.2 to 25 mm. Precipitation particles can have a velocity of from 0.2 to 20 m/s. Precipitation particles are categorized as Drizzle; Drizzle with rain; Rain; Rain, drizzle with snow; Snow; Snow grains; Freezing rain; Hail (Messtechnik, 2009).

2.1 Instrument Specifications

Table 1 – Parsivel Disdrometer specifications (Messtechnik, 2009).

Optical sensor laser diode	Wavelenght	780 nm
	Output power	0.5 Mw
Beam size (W x D)		180 x 30 mm
Measurement surface		54 cm2, recognition of edge events
Measuring range	Particle size of liquid precipitation	0.2 – 5 mm
	Particle size of solid precipitation	0.2 – 25 mm
	Particle speed	0.2 – 20 m/s
Design		32 precipitation size classes
		32 speed classes
		Radar reflectivity Z, kinetic energy
Weather code		SYNOP $w_a w_a$
		SYNOP ww
		NWS
		METAR/SPECI w'w' differentiation of the precipitation types drizzle, rain, hail, snow > 97% compared to a weather observer
Visibility in precipitation		100-5000 m
Rain rate	Minimum intensity	0.001 mm/h drizzle rain
	Maximum intensity	1,200 mm/h
	Accuracy	+- 5% (liquid) / +-20% (solid)

3.0 Data Collection and Processing

3.1 Description of Data Collection

The OTT Parsivel2 detects precipitation optically by a laser sensor that produces a horizontal strip of light. If a precipitation particle passes through the laser beam, it blocks off a portion of the beam corresponding to its diameter, reducing the output voltage. This voltage change determines the particle size. To measure the particle speed, the duration of the signal is calculated from when the particle enters the light strip until it leaves the light strip (Messtechnik, 2009).

From the particle size and speed, the following parameters can be derived: Size spectrum, type of precipitation, kinetic energy, intensity of the precipitation, radar reflectivity and visibility (Messtechnik, 2009). Most of these variables are present on the level 1 file, as described below.

3.2 Description of Derived Parameters

A set of derived parameters is included in a level 2 file. These parameters are the mass-weighted mean diameter (D_m, equation 1), median volume diameter (D_0, equation 2), reflectivity-weighted mean diameter (D_Z, equation 3) and maximum diameter (D_{max}).

$$\mathrm{D}_m = \frac{\int D^4 N(D) dD}{\int D^3 N(D) dD} \tag{1}$$

$$\int_0^{D_0} D^3 N(D) dD = \int_{D_0}^{\infty} D^3 N(D) dD \tag{2}$$

$$\mathrm{D}_Z = \frac{\int D^7 N(D) dD}{\int D^6 N(D) dD} \tag{3}$$

Where D is the volume-equivalent spherical diameter in mm, N(D) is the particle size distribution ($m^{-3}mm^{-1}$) and dD is the width of the diameter class (Bringi and Chandrasekar, 2001, Brandes, 2004).

For the N(D) calculation, equations 4 and 5 (Raupach and Berne, 2015) were applied.

$$S_i = 10^{-6} L (B - \frac{D_i}{2}) \tag{4}$$

$$N(D) = \frac{1}{S_i \Delta D_i \Delta t} \sum_{v=1}^{32} \frac{C_{v,i}}{V_v} \tag{5}$$

Where S_i is the effective sampling area (m^2), L is the length of Parsivel bean (180 mm), B is the width of the bean (30 mm), D_i is the class centre equivolume drop diameter for the i^{th} class (mm), ΔD_i is the width of the i^{th} diameter class (mm), Δt is the measurement integration time (s), $C_{v,i}$ is the raw number of particles and V_v is the class center velocity of the v^{th} velocity class (m/s).

4.0 Data Format

4.1 Level 1 Inside-fence Parsivel

4.1.1 Data File Structure and File Naming Conventions

The Level 1 Inside-fence Parsivel disdrometer has daily DAT files, which are TAR compressed and have the following naming convention:

brm_YYYYMMDD_dsd2.dat.tar

4.1.2 Data Format and Layout

The Inside-fence Parsivel has a 10-second temporal resolution and each row corresponds to a 10-second observation, which leads to an 8640 rows in total per daily file. The file contains 14 variables distributed in columns, separated by commas.

4.1.3 List of Parameters with Units

Table 2. Format of daily Inside-fence Parsivel files.

Column	Description	Format	Unity
1	Day	00	
2	Month	00	
3	Year	0000	

4	Time (HHMM)	0000	
5	Seconds	00	
6	Rain Intensity	0000.000	mm/h
7	Number of Detected Particles	00000	
8	Weather Code METAR/SPECI	+RA	
9	Radar Reflectivity	00.000	dBZ
10	Visibility	00000	m
11	Volume Equivalent Diameter N(D)	00.000	$\log_{10}(1/m^3*mm)$
12	Fall Velocity v(D)	00.000	m/s
13	Number of Particle N(D)/v(D)	000	1
14	Rain Amount Accumulated	0000.00	mm

The 13rd column contains the raw data, corresponding to the number of particles for each diameter and velocity class. There are 32 classes for each diameter and velocity variables, shown in tables 3 and 4 (Patrick Gatlin, personal communication, February 11, 2016). This column has 1024 elements separated by semicolons, each corresponding to a diameter-velocity 32x32 matrix element. The first element corresponds to the diameter-velocity space coordinate [D1,v1], where D1 is the first diameter bin and v1 is the first velocity bin. The second element is [D2,v1] where D2 is the second diameter bin. And so on until the 32nd element is [D32,v1] where D32 is the 32nd diameter bin. The 33rd element is the coordinate [D1,v2], where v2 is the 2nd velocity bin. The 64th element is [D32,v2] and the 1024 and last element corresponds to [D32,v32].

Table 3 – Volume-equivalent Diameter bin definitions (Patrick Gatlin, personal communication, February 11, 2016).

Bin Number	**Bin Average (mm)**	**Bin Width (mm)**
1	0.062	0.125
2	0.187	0.125
3	0.312	0.125
4	0.437	0.125
5	0.562	0.125
6	0.687	0.125
7	0.812	0.125
8	0.937	0.125
9	1.062	0.125
10	1.187	0.125
11	1.375	0.250
12	1.625	0.250
13	1.875	0.250
14	2.125	0.250
15	2.375	0.250
16	2.750	0.500

17	3.250	0.500
18	3.750	0.500
19	4.250	0.500
20	4.750	0.500
21	5.500	1.000
22	6.500	1.000
23	7.500	1.000
24	8.500	1.000
25	9.500	1.000
26	11.000	2.000
27	13.000	2.000
28	15.000	2.000
29	17.000	2.000
30	19.000	2.000
31	21.500	3.000
32	24.500	3.000

Table 4 – Velocity bin definitions (Patrick Gatlin, personal communication, February 11, 2016).

Bin Number	**Bin Average (m/s)**	**Bin Width (m/s)**
1	0.050	0.100
2	0.150	0.100
3	0.250	0.100
4	0.350	0.100
5	0.450	0.100
6	0.550	0.100
7	0.650	0.100
8	0.750	0.100
9	0.850	0.100
10	0.950	0.100
11	1.100	0.200
12	1.300	0.200
13	1.500	0.200
14	1.700	0.200
15	1.900	0.200
16	2.200	0.400
17	2.600	0.400
18	3.000	0.400
19	3.400	0.400
20	3.800	0.400
21	4.400	1.000
22	5.200	1.000
23	6.000	1.000
24	6.800	1.000

25	7.600	1.000
26	8.800	2.000
27	10.400	2.000
28	12.000	2.000
29	13.600	2.000
30	15.200	2.000
31	17.600	3.000
32	20.800	3.000

Column 11 is the volume equivalent diameter field in $\log_{10}(1/m^3*mm)$, which has 32 elements separated by semi-colons. The first element is related to the first diameter class, second element to the second diameter class, etc. In a similar manner, the fall velocity field (column 12) also has 32 elements separated by semi-colons and each element is related to a velocity class.

Other columns contain the variables derived by the measured diameter and velocity data. The first five columns correspond to the time of the data, the sixth column to the rainfall intensity in mm/h, the seventh column corresponds to the number of detected particles in the 10-second frame, eighth column to the weather code METAR/SPECI, ninth column to the radar reflectivity in dBZ and the tenth column to the visibility in meters. In regards to the weather code METAR/SPECI column, the type of precipitation is based on the number of particles within the measurement range, and the precipitation code is determined from the precipitation intensity (mm/h). Table 5 presents the definition of the precipitation codes for the weather code METAR/SPECI.

Table 5 - METAR/SPECI Weather code (Patrick Gatlin, personal communication, February 11, 2016).

	Rain rate (mm/h)	METAR/SPECI code
No precipitation		NP
Drizzle	≤ 0.2	-DZ
	0.2-0.5	DZ
	≥ 0.5	+DZ
Drizzle with rain	≤ 0.2	-RADZ
	0.2-0.5	RADZ
	≥ 0.5	+RADZ
Rain	≤ 0.2	-RA
	0.5-7.5	RA
	≥ 7.5	+RA
Rain, drizzle with snow	≤ 0.5	-RASN
	>0.5	RASN
		+RASN

Snow	≤ 0.5	-SN
	0.5-2.5	SN
	≥ 2.5	+SN
Snow grains	≤ 0.5	-SG
	0.5-4.0	SG
	≥ 4.0	+SG
Freezing rain	≤ 0.4	-GS
	> 0.4	GS
		+GS
Hail	≤ 7.5	GR
	≥ 7.5	GR

4.2 Level 1 Outside-fence Parsivel

4.2.1 Data File Structure and File Naming Conventions

The Level 1 Outside-fence Parsivel disdrometer has daily CSV (i.e., comma delimited) files, are TAR compressed and have the following naming convention:

UAHBERM_P2_YYYYMMDD.csv.tar

4.2.2 Data format and Layout

The file has the following header, specifying all variables available in columns.

"Date,Time,Sensor voltage (V),Signal amplitude of Laserband,Heating current (A),Temperature in sensor (°C),Number of detected particles,MOR Visibility (m),Intensity (mm/h),Precipitation since start (mm),Weather code SYNOP WaWa,Radar reflectivity (dBz),Weather code NWS,Weather code METAR/SPECI,Spectrum"

As with the Inside-fence Parsivel, the Outside-fence Parsivel also has data in each row representing a 10-second sample, leading to a 8640 rows per file, without considering the header. The file contains 15 columns, which are separated by commas, as presented in detail in Table 2.

4.2.3 List of Parameters with Units

Table 6. Format of Daily Outside-fence Parsivel files.

Column	Description	Format	Unity
1	Date (YYYYMMDD)	00000000	
2	Time (HH:MM:SS)	00:00:00	
3	Sensor Voltage	00.0	V
4	Signal Amplitude of Laserband	00000	
5	Heating Current	0.00	A
6	Temperature in Sensor	00	°C
7	Number of Detected Particles	0	
8	MOR Visibility	00000	m
9	Rain Intensity	0.000	mm/h
10	Precipitation Since Start	00.00	mm
11	Weather Code SYNOP W_aW_a	0	
12	Radar Reflectivity	00.000	dBZ
13	Weather Code NWS	C	
14	Weather Code METAR/SPECI	NP	
15	Spectrum		

The Spectrum variable in column 15 contain the raw data, equivalent to the 13th Inside-fence Parsivel column, with 1024 elements representing 32x32 diameter x velocity matrix. Instead, data format is slightly different than Inside-fence Parsivel file because the OTT ASDO software[1] is used to output this variable. The data are enclosed with the following tags to signify the beginning and ending of the spectrum, respectively: <SPECTRUM>…</SPECTRUM>. Data elements are separated in semicolons as with the Inside-fence Parsivel data. If no particles were detected at a coordinate, then it is left empty (i.e., the element will be blank).

The first six columns correspond to the time of the data and sensor specifications such as voltage, signal amplitude of laser band, heating current and temperature. Other columns contain the variables derived by the measured diameter and velocity data. The seventh column corresponds to the number of detected particles in the 10-second time frame, eighth to the visibility in meters, ninth to the rainfall intensity in mm/h, tenth to the accumulated precipitation in mm, eleventh to the Weather code SYNOP W_aW_a, twelfth to the radar reflectivity in dBZ, thirteenth to the NWS weather code and the fourteenth column to the METAR/SPECI weather code. Table 7 shows the definition of the precipitation codes for the SYNOP W_aW_a and the NWS weather codes. For METAR/SPECI weather code, see table 5.

[1] http://www.ott.com/download/operating-instructions-parsivel-application-software-asdo/

Table 7 – SYNOP W_aW_a and NWS weather codes (Messtechnik, 2009).

	Rain rate (mm/h)	SYNOP W_aW_a code	NWS code
No precipitation		00	C
Drizzle	≤ 0.2	51	L-
	0.2-0.5	52	L
	≥ 0.5	53	L+
Drizzle with rain	≤ 0.2	57	RL-
	0.2-0.5	58	RL
	≥ 0.5	58	RL+
Rain	≤ 0.2	61	R-
	0.5-7.5	62	R
	≥ 7.5	63	R+
Rain, drizzle with snow	≤ 0.5	67	RLS-
	>0.5	68	RLS
			RLS+
Snow	≤ 0.5	71	S-
	0.5-2.5	72	S
	≥ 2.5	73	S+
Snow grains	≤ 0.5	77	SG
	0.5-4.0	77	SG
	≥ 4.0	77	SG
Freezing rain	≤ 0.4	87	SP
	> 0.4	88	SP
Hail	≤ 7.5	89	A
	≥ 7.5	89	A

4.3 Level 2 Parsivel Data

4.3.1 Data File Structure and File Naming Conventions

The Level 2 Parsivel disdrometer data for both inside and outside the fence has daily DAT files and are TAR compressed. The inside the fence file have the following naming convention:

ins_level2_YYYYMMDD.dat.tar

While the outside the fence file have the following naming convention:

out_level2_YYYYMMDD.dat.tar

4.3.2 Data Format and Layout

The Level 2 Parsivel data has a one minute temporal resolution, represented in each row on the file. The original temporal resolution of 10 seconds was integrated to one minute for the calculation of the level 2 parameters. The file contains 6 variables distributed in columns, separated by commas.

4.3.3 List of Parameters with Units

Table 8. Format of Level 2 Parsivel files.

Column	Description	Format	Unity
1	Date (YYYYMMDD)	00000000	
2	Time (HHMM)	0000	
3	Mass-weighted mean diameter D_m	00.000	mm
4	Median volume diameter D_0	00.000	mm
5	Maximum diameter D_{max}	00.000	mm
6	Reflectivity-weighted mean diameter D_Z	00.000	mm

5.0 Data Remarks

5.1 Missing Data Periods

The Inside-fence Parsivel disdrometer does have missing data for IOP 2 from 12:38:00 UTC (beginning of operations) to 13:49:20. The Outside-fence Parsivel disdrometer missing data periods are shown in Table 8.

Table 8 – Outside-fence Parsivel disdrometer missing data periods.

IOP	**Start time (UTC)**	**End time (UTC)**
Pre-VSE IOP	2016/02/24 07:28:40	2016/02/24 09:00:00
IOP Shakedown Mission	2016/03/01 19:56:10	2016/03/02 01:03:00
IOP 1	2016/03/14 07:31:00	2016/03/14 09:33:00

6.0 References

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