VORTEX-SE 2016 Portable In Situ Precipitation Stations (PIPS) Data Documentation

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1.0 Dataset Overview

1.1 Introduction

The Portable In Situ Precipitation Stations (PIPS) were deployed in convective storms in several Intensive Operating Periods (IOPs) during the 2016 VORTEX-SE field program. The primary purpose of these instruments was to collect drop size distribution (DSD) data along with standard meteorological surface observations for the characterization of rain microphysics in potentially tornadic storms in the Southeast-U.S.

1.2 Time period covered by the data and physical location

The nominal period of the 2016 VORTEX-SE field program ran from 1 March-30 April 2016. During this period, observations from up to four PIPS were collected at various locations in the following IOPs:

- IOP1 (03/14/16)

PIPS ID	Start time (UTC)	End time (UTC)	Lat (deg)	Lon (deg)	Elevation (m ASL)
PIPS1A	03/13/16 23:54:45	03/14/16 17:52:25	34.9612	-87.3703	232
PIPS1B	03/14/16 00:05:30	03/14/16 17:52:50	34.9612	-87.3703	231
PIPS2A	03/14/16 02:13:10	03/14/16 17:15:30	34.8265	-87.2936	201
PIPS2B	03/14/16 02:07:30	03/14/16 17:15:00	34.8265	-87.2937	200

- IOP2 (03/24/16)

PIPS ID	Start time (UTC)	End time (UTC)	Lat (deg)	Lon (deg)	Elevation (m ASL)
PIPS1A	03/24/16 15:34:40	03/24/16 22:17:10	34.4889	-86.9648	177
PIPS1B	03/24/16 18:21:32	03/24/16 20:26:17	34.7458	-86.9575	205
PIPS2A	03/24/16 14:02:22	03/24/16 21:47:02	34.6312	-86.9505	183

- IOP3 (03/31/16)

PIPS ID	Start time (UTC)	End time (UTC)	Lat (deg)	Lon (deg)	Elevation (m ASL)
PIPS1A	03/31/16 22:11:53	03/31/16 23:15:03	35.0465	-87.6775	254
PIPS1B	03/31/16 22:01:13	03/31/16 23:23:38	35.0841	-87.7199	276
PIPS2A	03/31/16 22:24:53	03/31/16 23:09:08	35.0157	-87.6717	227
PIPS2B	03/31/16 21:48:23	03/14/16 23:33:55	35.1515	-87.7442	326

- IOP4A (04/27/16)
- IOP4B (04/29/16)

PIPS ID	Start time (UTC)	End time (UTC)	Lat (deg)	Lon (deg)	Elevation (m ASL)

PIPS1B	04/29/16 21:06:31	04/29/16 23:50:42	33.8902	-87.6275	194
PIPS2A	04/29/16 20:57:21	04/30/16 00:00:34	33.9439	-87.6205	185
PIPS2B	04/29/16 21:37:31	04/29/16 23:30:11	33.7131	-87.6463	155

- IOP4C (04/30/16)

PIPS ID	Start time (UTC)	End time (UTC)	Lat (deg)	Lon (deg)	Elevation (m ASL)
PIPS1B	04/30/16 20:51:11	04/30/16 21:50:31	34.5765	-87.4038	213
PIPS2A_D1	04/30/16 19:17:11	04/30/16 20:22:21	34.6962	-87.6352	159
PIPS2A_D2	04/30/16 20:41:51	04/30/16 22:01:56	34.6257	-87.4758	187
PIPS2B	04/30/16 20:57:31	04/30/16 21:40:31	34.5620	-87.3527	217

In addition, during IOP4A-C, PIPS 1A was collocated with UMASS FMCW (lat: 34.6903 deg, lon: -86.8814 deg) and collected nearly continuous data from 04/27/16 22:51:13 to 05/01/16 15:35:01 UTC.

2.0 Instrument Description

The Portable In situ Precipitation Stations (PIPS) are instrumented metal-framed probes designed to be quickly deployed in rapidly evolving convective weather scenarios (Figure 1). Table 1 summarizes the instrumentation on each PIPS. Particle Size Distribution (PSD) data are recorded as counts in 32 velocity x 32 diameter bins (non-linearly spaced), along with several derived parameters at 10-s intervals (see further description below), while all other data are recorded at 1-s intervals to an onboard micro-SD card for later downloading and processing. Each PIPS is powered by a 12-volt lead-acid battery with a single charge lasting for 2-3 days of uninterrupted data collection under typical conditions.

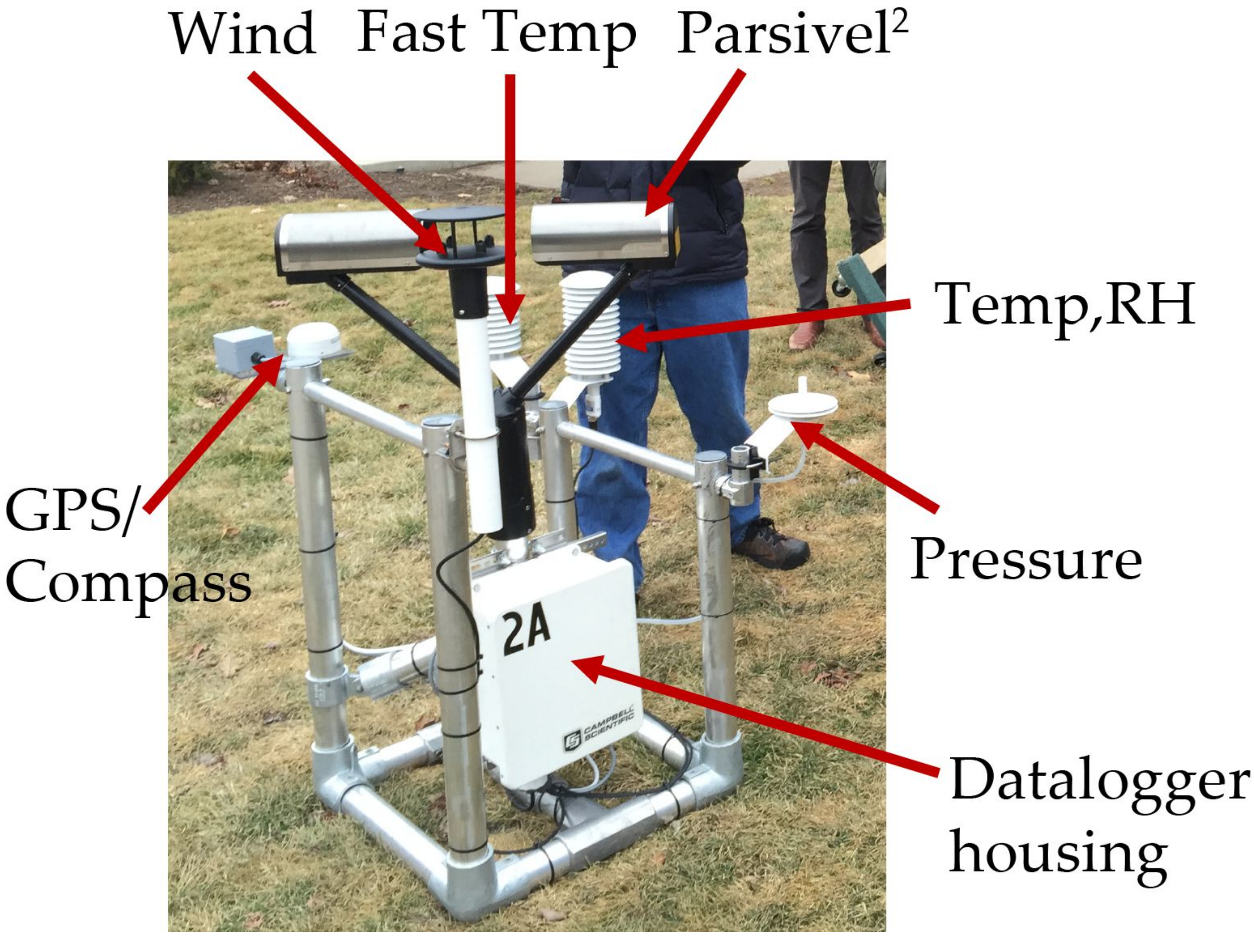

Figure 1. Photograph of a PIPS with instrumentation identified.

The following table summarizes the instrumentation available on each probe.

Table 1: Instrument details

Instrument	**Data interval (s)**	**Measurement height (m AGL)**	**Range/Accuracy**
OTT PARSIVEL² Laser Disdrometer	10	1.16	See Table 2
CS HMP155A Temp/RH sensor	1	0.84	**Source: https://www.campbellsci.com/hmp155a** **Temperature sensor**
			Range: -80 to 60 ℃ Accuracy: ∓0.226-0.0028 x T (-80 to 20 ℃) ∓0.055+0.0057 x T (20 to 60 ℃)

			Relative Humidity Sensor Range: 0.8 to 100% RH (non-condensing) Accuracy at 15 to 25℃: ±1% RH (0 to 90% RH) ±1.7% RH (90 to 100% RH) Accuracy at -60° to -40°C: ±(1.4 + 0.032 × reading) % RH Accuracy at -40° to -20°C: ±(1.2 + 0.012 × reading) % RH Accuracy at -20° to +40°C: ±(1.0 + 0.008 × reading) % RH Accuracy at 40° to 60°C: ± (1.2 + 0.012 × reading) % RH
CS 109SS-L Fast Temp sensor	1	0.84	**Source: https://www.campbellsci.com/109ss:** Range: -40° to +70°C Accuracy (Worst case): ±0.60 °C (–40 to 70 °C) ±0.49 °C (–20 to 70 °C)
Gill Windsonic1 anemometer	1	1.18	**Source: http://gillinstruments.com/products/anemometer/windsonic.htm** Range: 0 - 60 m s^{-1} Accuracy: ±2º @ 12 m s^{-1}
YoungUSA 61002 pressure port/Vaisala PTB210 barometer	1	0.36	**Source: http://www.vaisala.com/en/products/pressure/Pages/PTB210.aspx** Range: 500 - 1100 hPa Accuracy: ±0.30 hPa
KVH C100 Compass	1	0.84	**Source:http://www.kvh.com/Military-and-Government/Gyros-and-Inertial-Systems-and-Compasses/Compass-Sensors/All-Compass-Sensor-Systems/C100-Compass-Engine.aspx** Range: 0 - 359.9º Accuracy: ±0.5°
Garmin 010-00694-00 GPS	1	0.84	**Source: http://static.garmin.com/pumac/GPS_17x_HVS_Tech_Specs.pdf** GPS Standard Positioning Service (SPS) Position: < 15 meters, 95% typical Velocity: 0.1 knot RMS steady state • W AAS/EGNOS/MSAS Position: < 3 meters, 95% typical Velocity: 0.1 knot

			RMS steady state

Table 2: OTT Parsivel[2] abbreviated description (Messtechnik 2009)

Optical sensor laser diode	Wavelength	780 nm
	Output power	0.5 mW
	Beam size (W x L)	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	
Rain rate	Minimum intensity	0.001 mm/h drizzle rain
	Maximum intensity	1,200 mm/h
	Accuracy	±5 % (liquid) / ±20 % (solid)[1]

[1]Under laboratory conditions and statistically correlated by OTT calibration system with reference particle calibration of 0.5; 1.0; 2.0 and 4.0 mm
*size ranges are given for *internal classification* of liquid vs. solid particles. Sensor will measure liquid drops larger than 5 mm.

3.0 Data Collection and Processing

3.1 Description of Data Collection

Data from the conventional meteorological instruments (i.e. the temperature, relative humidity, wind direction and speed, and pressure), along with compass heading, GPS data, and other diagnostic information, are recorded at 1-s intervals to a micro-SD card on the onboard Campbell Scientific CR6 datalogger. A new data file containing the 1-s data is created every 10 min. A separate series of files (binned every 10 min) records the Parsivel 32x32 velocity/diameter count matrix (flattened into a single dimension), several derived parameters and diagnostic info, in 10-s intervals. These files are then converted from the datalogger format to raw text comma-delimited files. The series of 1-s and 10-s files are then merged into a single file for each PIPS and each deployment. In this merged file, each record contains the 1-s data, with every 10th record additionally containing the Parsivel datastream appended to the end of the 1-s data.

3.2 Description of derived parameters

Both the 1-s and 10-s data are processed to compute several derived parameters. For the 1-s data, the following derivations are computed when creating the merged dataset for each PIPS and each deployment (as described in section 3.1). The environmental (earth-relative) wind direction is derived from the compass heading and measured wind direction as WD = (CH + MWD) % 360, where CH and MWD are the compass heading and measured wind direction, in degrees, respectively. Dewpoint temperature is derived from the slow-response temperature and relative humidity using the Magnus formula:

$$T_d = 243.04 \times \frac{\log \frac{RH}{100} + \frac{17.625 \times T}{243.04 + T}}{17.625 - \log \frac{RH}{100} - \frac{17.625 \times T}{243.04 + T}}$$

Then, relative humidity is rederived following Richardson et al. (1998) using the derived dewpoint and the measured *fast-response* temperature as:

$$RH_{fast} = 100 \times \frac{\exp \frac{17.625 \times T_d}{243.04 + T_d}}{\exp \frac{17.625 \times T_{fast}}{243.04 + T_{fast}}}$$

Both the original RH and the derived RH are included in the output file.

The 10-s Parsivel datastream contains several internally derived parameters. Those included in the data files include precipitation intensity, total precipitation accumulation, and radar reflectivity.

4.0 Data Format

4.1 File Format and Naming Convention

Data are provided in ASCII comma-delimited format. Data files follow the naming convention:

PIPS_##_IOP_$$_D%.txt,

where ## is the PIPS identification string (one of 1A, 1B, 2A, 2B), $$ is the IOP string (one of 1,2,3,4A,4B,4C,4D), and % is the deployment number for the given IOP. For PIPS 1A during IOP 4A through IOP 4D, the file name is given as PIPS_1A_IOP_4A_4D_D1.txt.

4.2 File Structure

Each data file contains *comma delimited* records at 1-s intervals with the following token order:

Token #	Variable Name	Format	Units
1	Logger timestamp	YYYY-MM-DD HH:MM:SS	NA
2	Record number	integer	NA
3	Battery voltage	float	V
4	Logger panel temperature	float	℃
5	Wind direction (probe relative)	integer	degrees
6	Wind speed	float	m/s
7	Wind diagnostic flag	integer	0: Ok 1: Axis 1 failed 2: Axis 2 failed 4: Axis 1 and 2 failed 8: NVM error 9: ROM error
8	Fast-response temperature	float	℃
9	Slow-response temperature	float	℃
10	Relative Humidity	float	%
11	Station pressure	float	hPa
12	Compass direction	float	degrees (from true north)
13	GPS time	HHMMSS (integer)	NA
14	GPS status	char	A (valid position) or V (warning)
15	GPS latitude	DD.DM (float)	DD = degrees, DM = decimal minutes/100.
16	GPS latitude hemisphere	char	N or S
17	GPS longitude	DD.DM (float)	DD= degrees, DM = decimal minutes/100.

18	GPS longitude hemisphere	char	W or E
19	GPS speed	float	m/s
20	GPS direction	float	degrees (from true north)
21	GPS date	DDMMYY (integer)	NA
22	GPS magnetic variation	float	degrees
23	GPS altitude	float	m ASL
24	Wind direction (Earth relative)	float	degrees (from true north)
25	Dewpoint temperature	float	℃
26	RH (fast-temp derived)	float	%
27	Parsivel datastream (see next table). IMPORTANT, only present every 10th record. Set to NaN otherwise. Individual tokens within datastream delimited by semicolon.		

The Parsivel datastream, when present, appears at the end of the conventional data stream, is delimited by semicolons, and has the following format:

Token #	Variable Name	Format	Units
1	Parsivel Serial Number	integer	NA
2	Precipitation intensity	float	mm/h
3	Precipitation accumulation	float	mm
4	Radar reflectivity	float	dBZ
5	PSD sample interval	integer	s
6	Laser signal amplitude	integer	
7	Number of detected particles	integer	
8	Sensor temperature	integer	℃
9	Sensor voltage	float	V
10	Measurement time	HH:MM:SS	
11	Measurement date	DD:MM:YYYY	

12-1036	Particle spectrum*	integer	

*The particle spectrum is given as an unwrapped array of 32 diameter bins X 32 terminal velocity bins, with the diameter bins incrementing the fastest. That is, the first 32 values are the counts in each diameter bin for the *smallest* terminal velocity bin, the next 32 are the counts in each diameter bin for the next smallest velocity bin, and so on.

5.0 Data Remarks

5.1 Instrument and Data Quality Issues

These data should be considered preliminary. No quality-controlled procedures have as yet been applied to either the conventional data or the Parsivel data. However, analyses of instrument intercomparisons are ongoing and *overall* indicate a high degree of agreement between the four PIPS for both conventional and Parsivel data. Some outstanding issues include:

1. The Parsivel laser/sensor on PIPS 2B has a consistently lower signal strength than the other three instruments, and exhibits a systematic lack of sensitivity to light precipitation. We are currently investigating the cause and quantifying the degree of sensitivity loss.
2. Intercomparisons of wind direction between the PIPS suggest typical systematic differences on the order of 5 degrees.
3. Data from PIPS 2A and 2B after ~1015 UTC on 24 March 2016 are unreliable due to the probes being tipped onto their sides by agent or agents unknown. This was after the official end of IOP1.
4. Datalogger time stamps were synced with GPS prior to the start of each IOP. However, time differences of up to 3 s have been noted. It is recommended to use the first good GPS time stamp for each deployment to correct the datalogger timestamp if to-the-second accuracy is desired.
5. On the other hand, Parsivel timestamps (token 10 in the Parsivel datastream; see table above) were *not* synced with either the datalogger or GPS and should not be relied upon.
6. Related to #5, a datalogger configuration issue was discovered post-project in terms of the polling of the Parsivel datastream by the CR6 logger. Instead of synchronizing the Parsivel output upon powering up and booting of the datalogger and subsequently actively polling the Parsivel every 10 s thereafter, the datalogger was set to passively listen for the Parsivel telegram every 10 s. The effect of this difference in configuration is that it cannot be guaranteed that the 10-s time period of the PSD reported by the Parsivel exactly coincides with the 10-s intervals of the datalogger. This should be taken into account when attempting to match individual 10-s PSDs (such as for instrument intercomparisons), as an offset of up to 10 s in the worst case is possible. Thus, should intercomparisons at concurrent times be desired, it is recommended to integrate PSDs

over a period of 60-s or longer, to mitigate this time discrepancy. This issue has been corrected for the upcoming 2017 field program.

Instrument intercomparison studies are ongoing and a quality-controlled dataset with biases quantified and corrected (as appropriate) will be made available in the near future.

Regarding the accuracy of temperature sensors, a small discussion on response time is relevant. While various instruments specify a particular accuracy, it takes a finite amount of time for these sensors to respond to a given change, known as the response time or time constant. This response time is a combination of every factor influencing the measurement being made and thus represents an unknown quantity as it is impossible to completely describe every scenario in which the sensors are being used. This is of particular concern when dealing with rapidly changing environments. Do not equate the accuracies listed above to an absolute accuracy in heterogeneous ambient conditions.

Thus, the HMP155 (Tslow) temperature sensor for example may have a specified accuracy of approximately ± 0.2°C at 20°C, but may take upwards of 30 minutes to reach a final temperature following a large step change in the environment (e.g., Waugh 2012, Fig. 12). The Tslow and RH sensors are located inside a trapped volume enclosed by a microporous membrane that protects the RH probe from being contaminated by pollutants in the air stream (Waugh 2012). Although the membrane is porous to water vapor molecules (thus vapor pressure is equilibrated across the membrane), the temperature response of the volume inside the membrane is slowed and thus the measured Tslow and RH are not representative of the ambient environment outside of the membrane. Instead, a dew point (which is conserved across the membrane) is calculated using the Tslow and measured RH. Then, the dew point and Tfast are used to derive the ambient RH which is reported in the data following Richardson et al. (1998).

In contrast, the 109SS (Tfast) probe responds within a few tens of seconds to the environmental step change. This temperature measurement should be used for all temperature and temperature-related quantities.

6.0 References

Messtechnik, O.T.T., 2009. Operating instructions: present weather sensor—Parsivel

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Waugh, S., 2012: The "U-Tube": An improved aspirated temperature system for mobile meteorological observations, especially in severe weather. M.S. Thesis, University of Oklahoma, Norman, OK, 76 pp., [URI: http://hdl.handle.net/11244/24679]