DOE/SC-ARM/TR-137

ARM

CLIMATE RESEARCH FACILITY

Parsivel2
HANDBOOK

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U.S. DEPARTMENT OF ENERGY | Office of Science

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ARM's Handbook for the Parsivel2 Laser Disdrometer

MJ Bartholomew

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Contents

Figures

Tables

1.0 General Overview

In order to improve the quantitative description of precipitation processes in climate models, the ARM program has been collecting observations of the drop size spectra of rain events since early in 2006. ARM purchased Parsivel2 laser disdrometers with America Recovery Act funds and they have proven to be robust in the field. They make observations of the particle size distribution over the range of 0.06mm to 24mm and classify precipitation type. To date they have been deployed on board the Spirit Horizon during the MAGIC Field Campaign and one will be permanently deployed at East North Atlantic (ENA). ARM initially deployed impact disdrometers (TWPC1, TWPC3 and SGPC1). Each of the three units deployed was accompanied by a nearby tipping bucket. In 2010, the tipping buckets were upgraded to weighing buckets. Subsequently five video disdrometers were purchased. The purchase of the 6th video disdrometer is pending. The video disdrometers are permanently deployed at SGPC1, TWPC1, TWPC3 and in the near future at ENA. One video disdrometer is assigned to the ARM2. What follows is a detailed description of the Parsivel2 laser disdrometers and their datastreams.

2.0 Contacts

2.1 Mentor

Mary Jane Bartholomew
Brookhaven National Laboratory
MS 490D
Upton, NY 11973
Phone: 631-344-2444
Fax: 631-344-2060
bartholomew@bnl.gov

2.2 Vendor / Instrument Developers

Parsivel2 Disdrometers
OTT Hydromet GmbH
Ludwigstrasse 16
87437 Kempten
Germany
www.ott.com

In USA sold by
Hach Hydromet
P.O. Box 389
Loveland, CO 80539
www.hachhydromet.com

3.0 Deployment Locations and History

Table 1. Deployment Locations

Serial Number	Property Number	Location	Date Installed	Date Removed	Status
		MAGIC field campaign	2012/09/24	2013/09/26	
		ENA	2014/02/01	On going	

4.0 Near-Real-Time Data Plots

http://plot.dmf.arm.gov/plotbrowser/

5.0 Data Description and Examples

Data Streams
Xxxpars2Cn.00
Xxxpars2Cn.b1

5.1 Data File Contents

5.1.1 Primary Variables and Expected Uncertainty

The variables for the disdrometer listed in Tables 1 thru 4. The performance of the Parsivel2 disdrometer has not been studied. The performance of an earlier model of Parsivel disdrometer, however, was evaluated in a field study. In this study three different types of disdrometers of observed the same rain events for 6 months (Tokai et al., 2013). If the second model's performance is like the first one then, in terms of median volume diameter, the Parsivel showed an absolute % bias of 9.7 and 11.8 in comparison to the 2-dimensional video disdrometer and Josss-Waldvogel impact disdrometer respectively. In terms of liquid water content the absolute % bias values were 17.5 and 21.3 respectively.

The Parsivel2 assigns a precipitation classification whenever precipitation is observed. The precipitation categories are listed below:

- Drizzle
- Drizzle with rain
- Rain
- Rain, drizzle with snow
- Snow
- Snow grains
- Freezing rain
- Hail.

5.1.1.1 Primary Variables

Table 2. Parsivel2 Datastream

Quantity	Variable	Measurement Interval	Units	Comments
base time in epoch	base_time	1 min	seconds since YYYY-mm-dd XX:XX:XX X:XX	
time offset from base_time	time_offset	1 min	seconds since YYYY-mm-dd XX:XX:XX X:XX	
time offset form midnight	time	1 min	seconds since YYYY-mm-dd XX:XX:XX X:XX	
north latitude	lat	constant	degrees	permanent deployments have constant latitude; latitude from ship board deployments is contained is separate navigation datastreams
east longitude	lon	constant/ variable	degrees	Permanent deployments have constant longitude; longitude from ship board deployments is contained in separate navigation datastreams
altitude	alt	constant/ variable	meters above sea level	
number of drops/particless	number_detected_ particles	1 min	counts	
weather code	weather_code	1 min	integer	SYNOP WaWa Table 4680
average diameter of particle class	particle_size	1 min	millimeters	
precipitation rate	precip_rate	1 min	millimeters/hour	
smallest particle	diameter_min	1 min	millimeters	
largest particle	diameter_max	1 min	millimeters	
moments of particle size distribution	moment1…moment6	1 min	mm/m^3, mm^2/m^3, mm^3/m^3, mm^4/m^43 mm^5/m^3, mm^6/m^3	
number density	Number_density	1 min	$1/(m^3 \cdot m)$	

Quantity	Variable	Measurement Interval	Units	Comments
raw fall velocity	raw_fall_velocity	set of 32constants	m/s	
fall velocity after Lhermite	fall_velocity_calculated	set of 32constants	m/s	Lhermite, 2002
raw particle size distribution	raw_spectrum		counts	matrix (32 x 32) of counts for particles observed in 32 possible particle classes at 32 possible fall velocities
class size width	class_size_width		mm	
median volume diameter	median_volume_diameter	1 min	mm	
liquid water distribution mean	liquid_water_distribution_ mean	1 min	millimeters	
liquid water content	liquid_water_content	1 min	mm^3/m^3	
radar reflectivity	equivalent_radar_ reflectivity	1 min	dBZ	S band
radar reflectivity	equivalent_radar_ reflectivity_ott	1 min	dBZ	S band reflectivity determined by OTT software
distribution slope	lambda	1 min	1/mm	assumes Marshall-Palmer distribution
distribution intercept	intercept_parameter	1 min	1/(meters^3 · millimeters)	assumes Marshall-Palmer distribution
Mor visibility	mor_visibility	1 min	m	
laser band amplitude	laser_band_amplitude	1 min	counts	
sensor temperautre	sensor_temperature	1 min	degrees C	
heating current	heating_current	1 min	amps	
sensor voltage	Sensor_voltage	1 min	volts DC	

Note: lat/lon/alt refers to the ground where the instrument is sited, NOT the height of the sensor.

5.1.1.2 Expected Uncertainty

The performance of the Parsivel2 disdrometer has not been studied. The performance of an earlier model of Parsivel disdrometer, however, was evaluated in a field study. In this study three different types of disdrometers of observed the same rain events for 6 months (Tokai et al., 2013). If the second model's performance is like the second one then, in terms of median volume diameter, the Parsivel showed an absolute % bias of 9.7 and 11.8 in comparison to the 2-dimensional video disdrometer and Josss-Waldvogel impact disdrometer respectively. In terms of liquid water content the absolute % bias values were 17.5 and 21.3 respectively.

Table 3. Particle Class Specifics for Parsivel2 Disdrometer Observations

Diameter mm	Width mm	Ott Fall Velocity m/s	Lhermite Velocity m/s
0.0620	0.1250	0.0500	0.2770
0.1870	0.1250	0.1500	0.8220
0.3120	0.1250	0.2500	1.3510
0.4370	0.1250	0.3500	1.8630
0.5620	0.1250	0.4500	2.3550
0.6870	0.1250	0.5500	2.8280
0.8120	0.1250	0.6500	3.2810
0.9370	0.1250	0.7500	3.7140
1.0620	0.1250	0.8500	4.1250
1.1870	0.1250	0.9500	4.5160
1.3750	0.2500	1.1000	5.0640
1.6250	0.2500	1.3000	5.7210
1.8750	0.2500	1.5000	6.2990
2.1250	0.2500	1.7000	6.8010
2.3750	0.2500	1.9000	7.2330
2.7500	0.5000	2.2000	7.7620
3.2500	0.5000	2.6000	8.2820
3.7500	0.5000	3.0000	8.6330
4.2500	0.5000	3.4000	8.8610
4.7500	0.5000	3.8000	9.0050
5.5000	1.0000	4.4000	9.1200
6.5000	1.0000	5.2000	9.1780
7.5000	1.0000	6.0000	9.1950
8.5000	1.0000	6.8000	9.1990
9.5000	1.0000	7.6000	9.2000
11.000	2.0000	8.8000	9.2000
13.000	2.0000	10.400	9.2000
15.000	2.0000	12.000	9.2000
17.000	2.0000	13.600	9.2000
19.000	2.0000	15.200	9.2000
21.500	3.0000	17.600	9.2000
24.000	3.0000	20.800	9.2000

5.1.1.3 Definition of Uncertainty

This section is not applicable to this instrument.

5.1.2 Secondary / Underlying Variables

This section is not applicable to this instrument.

5.1.3 Diagnostic Variables

This section is not applicable to this instrument.

5.1.4 Data Quality Flags

If the data is missing for a sample time, a "missing_value" value of -999 is assigned to that field.

Table 4. Parsivel2 Disdrometer Data Quality Variables

Quantity	Variable	Measurement Interval	Min	Max	Delta
sample time	qc_time	1 min			
number of particles		1 min	0	none	N/A
precip rate		1 min	0	none	N/A
diameter max		1 min	0	24	
diameter min		1 min	0	24	

5.1.5 Dimension Variables

Table 5. Disdrometer Dimension Variables

Quantity	Variable	Measurement Interval	Unit
Base time in Epoch	base_time	1 min	seconds since YYYY-mm-dd XX:XX:XX X:XX
Time offset from base_time	time_offset	1 min	seconds since YYYY-mm-dd XX:XX:XX X:XX
Time offset form midnight	time	1 min	seconds since YYYY-mm-dd XX:XX:XX X:XX
north latitude	lat	once	degrees
east longitude	lon	once	degrees
altitude	alt	once	meters above sea level

Note: lat/lon/alt refers to the ground where the instrument is sited, NOT the height of the sensor.

5.2 Annotated Examples

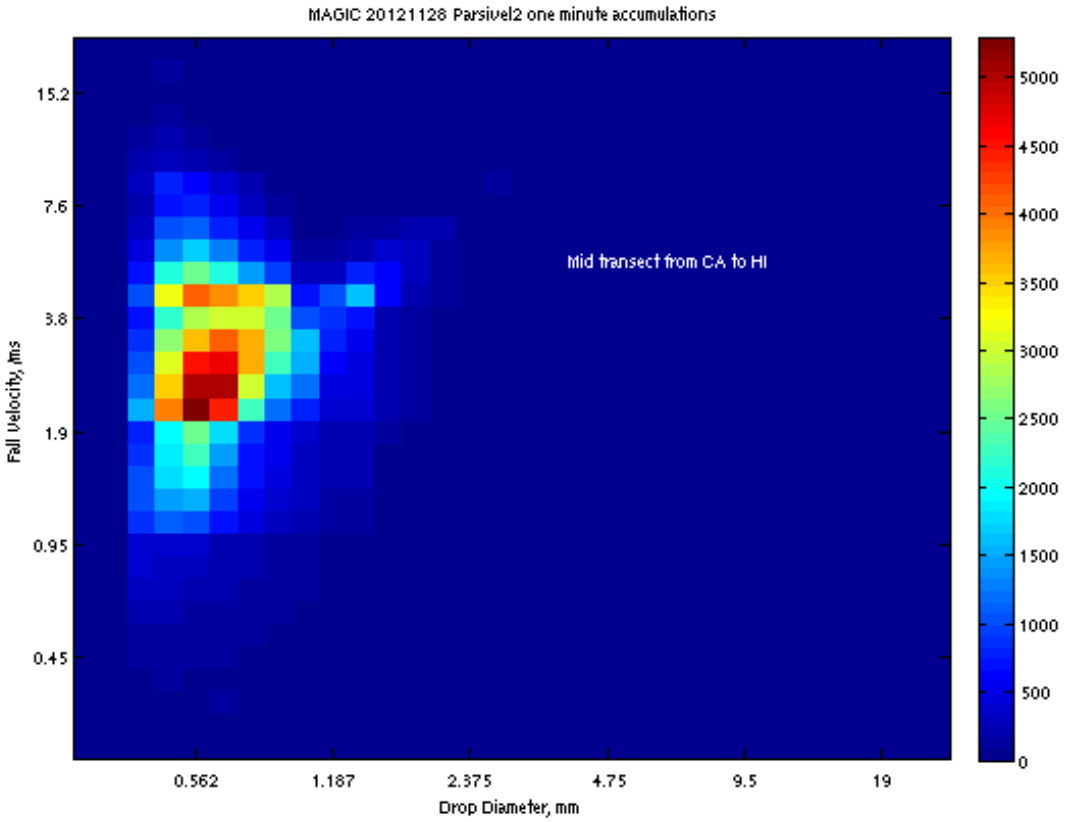

Figure 1. Two dimensional histogram of the drop size distribution observed during MAGIC Field Campaign. This figure shows the sum of all observations over a three hour rain event with rain rates varying from 0 to 10mm/hr. Note that neither the x nor the y axis is linear in this plot.

5.3 User Notes and Known Problems

This section is not applicable to this instrument.

5.4 Frequently Asked Questions

This section is not applicable to this instrument.

6.0 Data Quality

6.1 Data Quality Health and Status

The following links go to current data quality health and status results:

- DQ HandS (Data Quality Health and Status)
- NCVweb for interactive data plotting using.

The tables and graphs shown contain the techniques used by ARM's data quality analysts, instrument mentors, and site scientists to monitor and diagnose data quality.

6.2 Data Reviews by Instrument Mentor

- **QC frequency:** Once or twice a week
- **QC delay:** Three days behind the current day
- **QC type:** DSview plots for instrument operation status, otherwise DQ HandS diagnostic plots
- **Inputs:** None
- **Outputs:** DQPR and DQR as needed
- **Reference:** None.

6.3 Data Assessments by Site Scientist / Data Quality Office

All Data Quality Office and most Site Scientist techniques for checking have been incorporated within DQ HandS and can be viewed there.

6.4 Value-Added Procedures and Quality Measurement Experiments

Many of the scientific needs of the ARM Program are met through the analysis and processing of existing data products into "value-added" products or VAPs. Despite extensive instrumentation deployed at the ARM sites, there will always be quantities of interest that are either impractical or impossible to measure directly or routinely. Physical models using ARM instrument data as inputs are implemented as VAPs and can help fill some of the unmet measurement needs of the program. Conversely, ARM produces some VAPs, not in order to fill unmet measurement needs, but to improve the quality of existing measurements. In addition, when more than one measurement is available, ARM also produces "best estimate" VAPs. A special class of VAP, called a Quality Measurement Experiment (QME), does not output geophysical parameters of scientific interest. Rather, a QME adds value to the input datastreams by providing for continuous assessment of the quality of the input data based on internal consistency checks, comparisons between independent similar measurements, or comparisons between mea

7.0 Instrument Details

7.1 Detailed Description

The OTT Parsivel2 is a laser optical system housed in a metal "Y" shaped structure (Figure 2). A structure at the end of one branch of the "Y" houses the laser. The structure atop the other branch of the "Y" holds the detector. The field of view is midway between the transmitter and detector. The base of the "Y" is recessed to accommodate a vertical mounting pole for instrument deployment. Typically the device is set up at a height of ~6 feet (2 meters). Because the device weighs ~14lbs (6.4kg), a stable base like a concrete pad must be used to support the instrument. The instrument's physical dimensions are 670mm x 600mm x 114mm.List of Components

The laser operates at a wavelength of 780nm with output power of 0.5mW spread out over a beam 30mm wide. Class 1 (21 CFR 1040.10 and 1040.11) also 1 (IEC/EN 60825-1 A2:2001).

7.1.1 List of Components

1. Parsivel2 device with 10m cable
2. RS485 to CAT5 converter (Nport MOXA 5520)
3. Power supply
4. Enclosure for power supply and converter (power supply and converter located indoors)
5. Computer for instrument control and data acquisition
6. Software for instrument control and monitoring, manufacturer's Application Development System Online (ADSO) software.

Figure 2. Parsivel2 Device: The transmitter is located in one housing and the detector is in the other.

7.1.2 System Configuration and Measurement Methods

7.1.2.1 The Data Acquisition Cycle

During normal operation the disdrometer samples for one minute.

7.1.2.2 Firmware Overview

This section is not applicable to this instrument.

7.1.2.3 Processing Received Signals

The disdrometer's manufacturer provided software for data acquisition, analysis and inspection. In the case of the Parsivel2, the program is called ADSO and it runs on a personal computer using Windows7. ARM has always a virtual version of ARM's Core PC for this instrument.

7.1.2.4 Siting Requirements

The disdrometer needs a level firm base and an environment free from local wind distortions. Ideally it should be orientated perpendicular to prevailing winds.

7.1.3 Specifications

This section is not applicable to this instrument.

7.2 Theory of Operation

The OTT Parsivel2 is a laser optical system that produces a horizontal strip of light. Particles that pass thru the light block a portion of the beam corresponding to their diameter. To determine particle speed, the duration of the diminished signal is measured.

7.3 Calibration

None required

7.3.1 Theory

This section is not applicable to this instrument.

7.3.2 Procedures

This section is not applicable to this instrument.

7.3.3 History

This section is not applicable to this instrument.

7.4 Operation and Maintenance

7.4.1 User Manual

This section is not applicable to this instrument.

7.4.2 Routine and Corrective Maintenance °Documentation

Frequency: weekly

Inspection of site grounds near the instrument: Visually check the site grounds around the instrument for hazards such as rodent burrows, buried conduit trench settling, and insect nests.

Checklist response:

- No Problems Noted
- Problem - Enter any applicable comments for this PM Activity

Visual inspection of instrument components:

Conduit, Cables, and Connectors: Check that all the conduits on the bottom of the control boxes are secure. Check all conduits from the control boxes to the sensors for damage. Check all sensor wires inside the control box for tightness and damage. Check all the connections at the sensors for damage, water intrusion, and tightness.

Checklist response:

- No Problems Noted
- Problem - Enter any applicable comments for this PM Activity

Check screen for error messages and current weather conditions:

Checklist response:

- No Problems Noted
- Problem - Enter any applicable comments for this PM Activity

Active maintenance and testing procedures:

Disdrometer maintenance: Keep sensor free of leaves and/or other debris.

Disdrometer testing: Precipitation events should show particles accumulating in particle vs velocity plot.

Checklist response:

- No problems noted
- Problem - Enter any applicable comments for this PM Activity.

7.4.3 Software Documentation

Disdrometer: Ingest software.

7.4.4 Additional Documentation

This section is not applicable to this instrument.

7.5 Glossary

This section is not applicable to this instrument.

7.6 Acronyms

Also see the ARM Acronyms and Abbreviations.

7.7 Citable References

Tokay, A., W Peterson, P Gatlin, and M Wingo, 2013. "Comparison of raindrop size distribution measurements by collocated disdrometers." *Journal of Atmospheric and Oceanic Technology* 30: 1672-1690. doi:10.1175/JTECH-D-12-00163.1.

7.8 Formulas Used in Data Processing

The following quantities are calculated for a distribution with a time interval t:
R Rainfall rate, [mm/h]
RA Rain amount, [mm]
W Liquid water content, [mm^3/m^3]
Z Radar reflectivity factor, [mm^6/m^3]
ZdB Radar reflectivity factor, [dB]
Dmax Largest drop registered, [mm]
N_0 [$1/(m^3.mm)$]
Λ Slope, [1/mm]
N(Di) the number density of drops of the diameter corresponding to size class i per unit volume, [$1/(m^3.mm)$]

Input Data:
n_i number of drops measured in drop size class i during time interval t
D_i average diameter of the drops in class i mm
F size of the sensitive surface of the disdrometer m^2
F = 0.0054 m^2
t time interval for measurement s
t = 60 s (standard value)
$v(D_i)$ fall velocity of a drop with diameter D_i m/s
ΔD_i diameter interval of drop size class i mm, see drop size classes below

$$R = \frac{\pi}{6} \cdot \frac{3.6}{10^3} \cdot \frac{1}{F \cdot t} \cdot \sum_{i=1}^{20} (n_i \cdot D_i^3)$$

$$RA = R \cdot t/3600$$

$$RT = \sum RA$$

$$W = \frac{\pi}{6} \cdot \frac{1}{F \cdot t} \cdot \sum_{i=1}^{20} \left(\frac{n_i}{v(D_i)} \cdot D_i^3\right)$$

$$Wg = W/1000$$

$$Z = \frac{1}{F \cdot t} \cdot \sum_{i=1}^{20} \left(\frac{n_i}{v(D_i)} \cdot D_i^6\right)$$

$$ZdB = 10 \cdot \log Z$$

$$EK = \frac{\pi}{12} \cdot \frac{1}{F} \cdot \frac{1}{10^6} \cdot \sum_{i=1}^{20} \left(n_i \cdot D_i^3 \cdot v(D_i)^2\right)$$

$$EF = EK \cdot 3600/t$$

Dmax

$$N_0 = \frac{1}{\pi} \cdot \left(\frac{6!}{\pi}\right)^{\frac{4}{3}} \cdot \left(\frac{W}{Z}\right)^{\frac{4}{3}} \cdot W$$

$$\Lambda = \left(\frac{6!}{\pi} \cdot \frac{W}{Z}\right)^{\frac{1}{3}}$$

$$N(D_i) = \frac{n_i}{F \cdot t \cdot v(D_i) \cdot \Delta D_i}$$

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