DOE/SC-ARM-TR-111

Two-Dimensional Video Disdrometer (VDIS) Instrument Handbook

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DISCLAIMER

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Acronyms and Abbreviations

2D	two-dimensional
ARM	Atmospheric Radiation Measurement
CCD	charged-coupled device
DQ	data quality
DQPR	Data Quality Problem Report
DQR	Data Quality Report
PM	preventive maintenance
QC	quality control
QME	Quality Measurement Experiment
SGP	Southern Great Plains
TWP	Tropical Western Pacific
VAP	value-added product
VDIS	video disdrometer

Contents

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Tables

1.0 General Overview

In order to improve the quantitative description of precipitation processes in climate models, the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility has been collecting observations of the drop size spectra of rain events since early in 2006 with impact disdrometers. While ARM is primarily interested in their contribution to the understanding of precipitation processes, disdrometers can also be used for traffic control, airport observation systems, and hydrology. The latest disdrometers employ microwave or laser technologies. Two-dimensional (2D) video disdrometers (VDIS) make the most detailed and complete observations of hydrometeor shape and fall velocity.

Four of ARM's five video disdrometers are deployed; the last is a spare. This handbook provides a detailed description of the instruments and their datastreams.

2.0 Contacts

2.1 Mentor

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2.2 Instrument Developers

Video Disdrometers
Joanneum Research
Steyergasse 17
A-8010 Graz
Austria
http://www.joanneum.at/

3.0 Deployment Locations and History

	Begin	**End**
Darwin, ARM TWPC3	February 2011	Ongoing
Manus, ARM TWPC1	Fall 2011	Ongoing
Southern Great Plains, SGPC3	February 2011	Ongoing
AMF2	Varies with AMF2 deployment	

4.0 Near-Real-Time Data Plots

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

5.0 Data Descriptions and Examples

5.1 Data File Contents

Video Disdrometer Datastreams

XxxvdisCn.b1
XxxvdisdropsCn.b1
XxxvdisCn.00.*ab*
XxxvdisCn.00.*abh*
XxxvdisCn.00.*hd*
XxxvdisCn.00.*hyd*
XxxvdisCn.00.*vid*
Where xxx = three letter site designation, n = the site number

5.2 Primary Variables and Expected Uncertainty

The variables for the disdrometer and rain gauge datastreams are listed in Tables 1,2, 4, and 5.

Table 1. Video disdrometer variables in VDIS datastream.

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	constant	degrees
east longitude	lon	constant	degrees
altitude	alt	constant	meters above sea level
instrument serial number	serial_number	constant	
Center diameter of drop size bin	drop_diameter	1min	millimeters
Number of drops per bin	num_drops	1 min	unitless
Number density	num_dendisy	1min	1/m^3 mm

Quantity	Variable	Measurement interval	Unit
Rain amount	rain_amount	1min	millimeters
Rain rate	rain_rate	1min	Millimeters/hour
Total number of drops	total_drops	1min	unitless
Liquid water content	liquid_water_ Content	1min	mm^3/m^3
Smallest drop observed	diameter_min	1min	millimeters
Largest drop observed	diameter_max	1min	millimeters
Calculated radar reflectivity	radar_reflectivity	1min	mm^6/m^3
Marshall-Palmer intercept parameter	intercept_parameter	1min	1/m^3mm
Marshall-Palmer slope parameter	slope_parameter	1min	1/mm
Median volume diameter	mediam_volume_ diameter	1min	millimeters
Liquid water distribution mean	liquid_water_ Distribution-mean	1min	millimeters
First thru sixth moments of the distribution	moment1…moment6	1min	mm^1/m^3…mm^6/m^3
Width of bins	bin_width	Const	millimeters

Table 2. Video disdrometer variables from VDISDROPS datastream.

Quantity	Variable	Measurement interval varies with each drop	Unit
base time in Epoch	base_time	varies	seconds since YYYY-mm-dd XX:XX:XX X:XX
time offset from base_time	time_offset	varies	seconds since YYYY-mm-dd XX:XX:XX X:XX
time offset form midnight	time	varies	seconds since YYYY-mm-dd XX:XX:XX X:XX
north latitude	lat	constant	degrees
east longitude	lon	constant	degrees
altitude	alt	constant	meters above sea level

Quantity	Variable	Measurement interval varies with each drop	Unit
Equivolumetric sphere diameter	equivolmetric_sphere_ Diameter	varies	millimeters
Volume of drop	drop_volume	Varies	mm^3
Fall speed of drop	fall_speed	Varies	m/s
Oblateness of drop	oblateness	Varies	unitless
Effective Measurement area of instrument	area	Varies	mm^2
Height of drop as observed by camera a	drop_height_a	Varies	mm
Height of drop as observed by camera b	drop_height_b	Varies	mm
Width of drop as observed by camera a	drop_width-a	Varies	mm
Width of drop as observed by camera b	drop_width_b	Varies	mm

5.3 Expected Uncertainty

The percent fractional standard errors for the mass-weighted mean diameter (Dm) and rain rate (R) as observed by the video disdrometers vary with rain rate and were determined to be (Thurai et al. 2011, Bringi 2011) as follows.

Table 3. Video disdrometer fractional standard errors for mass-weighted mean diameter (D_m) and rain rate (R).

Rain rate	D_m	R
R<= 3 mm/hr	7.24	20.39
3< R <= 10 mm/hr	4.30	11.28
10 < R <=30 mm/hr	3.75	13.61
30 < R mm/hr	4.69	12.42

5.4 Definition of Uncertainty

N/A

5.5 Secondary/Underlying Variables

N/A

5.6 Diagnostic Variables

N/A

5.7 Data Quality Flags

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

Table 4. Video disdrometer data quality variables.

Quantity	Variable	Measurement interval	Min	Max	Delta
sample time	qc_time	1 min			
equiivolumetric diameter	qc_diameter_min	1 min	0	10	N/A
equivolumetric diameter	qc-diameter-max	1min	0	10	
liquid water content	qc_liquid_water_content	1 min	0	none	N/A
liquid water distribution mean	qc_liquid_water_distribution_mean	1 min	0	none	N/A
median volume diameter	qc_median_volume_ diameter	1 min	0	10	
number of drops	qc_number_drops	1 min	0		
rain amount	qc_rain_amount	1 min			
rain rate	qc_rain_rate	1 min			
slope parameter	qc_slope_parameter	1 min			
total drops	qc_total_drops	1 min			

5.8 Dimension Variables

Table 5. Video 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
Video disdrometer Width of bins	bin_width	constant	0.2mm

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

6.0 Annotated Examples

N/A

7.0 User Notes and Known Problems

Outliers in the Data

It is common to find outliers in disdrometer data and they should be filtered out to obtain the best-quality data. Some hydrometeors will fall on the edge of the instrument’s field of view. These will show up in the data as small drops moving too fast for their expected terminal fall speed. Other hydrometeors may enter the instrument’s field of view after splashing on the device. These will show up as large drops with fall speeds less than expected for their terminal fall speed. Furthermore, insects, leaves, spider webs, etc. can lead to anomalous results. Most common outliers are screened by removing those with fall speeds greater than or less than 50% of Gunn and Kinzer (1949) empirically derived terminal fall speeds for rain drops. The raw data are provided in the b1-level files and researchers can choose what level of filtering they desire. Some may choose to use a maximum diameter threshold as well.

8.0 Frequently Asked Questions

Equations used to calculate certain variables in the vdis datastream

Variable name	Units
W- liquid water content	mm^3/m^3
Z - radar reflectivity factor, S band	mm^6/m^3
N_0 - intercept parameter, assuming an ideal Marshall-Palmer type distribution	1/m^3mm
Λ - slope parameter, assuming an ideal Marshall-Palmer type distribution	1/mm
D_0 - median volume diameter, assuming an ideal Marshall-Palmer type distribution	mm
D_m - liquid water distribution mean, assuming an ideal Marshall-Palmer type distribution	mm

TotalDrops - total number of drops	
Dmin - diameter of smallest drop observed	mm
Dmax - diameter of largest drop observed	mm
moment1...moment6 - moments from the observed distribution	

$W = pi/(6*t) * \Sigma(D_i{}^\wedge 3/A_i*v_i)$

where

A is the effective measurement area for the drop from vdisdrops in m^2

t is the length of the observation period, default 60 seconds

i ith drop
D_i is the equivolumetric sphere diameter of drop i from drops.txt in m^2
v_i is the fall velocity of drop in m/s from vdisdrops in m^2

Z = 1/(t)* Σ(D_i^6/A_i*v_i)

N_0 =1/pi * (6!/pi)^1.333 * (W/Z)^1.333 * W

Λ = (6!/pi *W/Z)^0.333

D_0 = 3.67/Λ
D_m = 4.0/Λ

moments calculation
M_n=sum(D^n * j *0.2)
where n = moment number
j = number of drops in bin

9.0 Data Quality

9.1 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.

9.2 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.

9.3 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.

9.4 Value-Added Procedures and Quality Measurement Experiments

Many of the scientific needs of the ARM facility 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 facility. 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 measurement with modeled results, and so forth. For more information, see the VAPs and QMEs web page.

10.0 Instrument Details

The operational principle of the compact 2D video disdrometer is depicted schematically in Figure 1:

The device contains two optical paths, labeled A and B henceforth. Each optical path consists of an illumination unit, which provides the background illumination by means of a halogen lamp, a mirror, and a Fresnel lens. The latter component’s focal length plus the optical parameter of the cameras object lens determine the shape of the light cone and the distance towards the center of the measurement area.

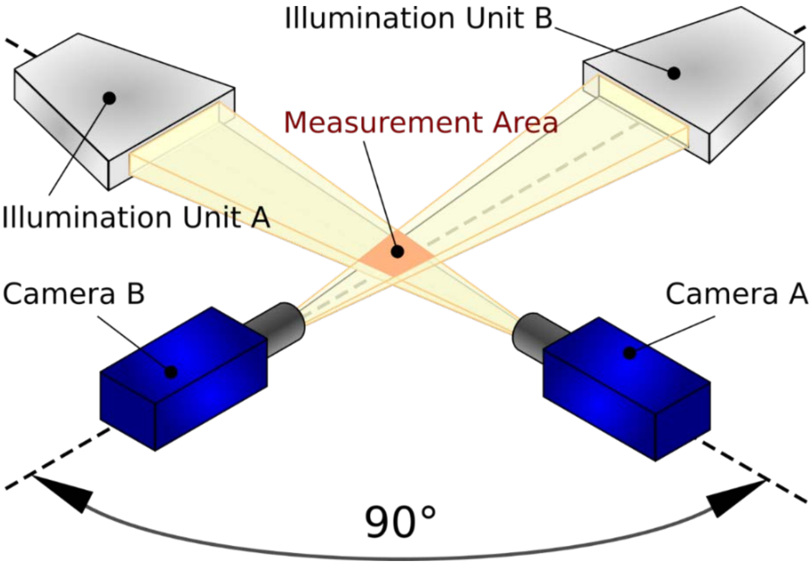

Figure 1. Measurement principle of the compact 2D video disdrometer.

The two charged-coupled device (CCD) line-scan cameras are directed towards the opening of the illumination units. Objects passing the measurement area – which is determined by the cross-section of the two optical paths as seen from above – obstruct the light and are detected as shadows by the cameras. Further optical elements of the light paths, which have been omitted from this picture for the sake of simplicity – are two mirrors and a pair of slit plates that contribute to the compact dimensions of the device and its insensitivity with respect to spray.

Each camera contains a small embedded computer responsible for handling the data capture process, the analysis of the data, and its conversion and compression into a format suitable for further processing and transporting to the indoor user terminal (not in picture). In order to identify individual precipitation particles by matching their views as seen from camera A and B, it is necessary to synchronize the shutter and capture control of both cameras. To this end, both cameras use a synchronous line trigger signal.

To reconstruct observables like falling velocity, oblateness, etc. from the datastreams of the two cameras, the two optical paths are displaced vertically by a distance of, typically, about 6mm. Measuring this distance and adjusting the background illumination are the two major calibration and maintenance tasks necessary for successful operation of the device.

10.1 Detailed Description

See OU_V102.pdf for the video disdrometer details.

10.2 List of Components

N/A

11.0 System Configuration and Measurement Methods

11.1 The Data Acquisition Cycle

During normal operation, all disdrometers make periodic one-minute observations.

11.2 Firmware Overview

N/A

11.3 Processing Received Signals

The video disdrometer software is called the Indoor User Terminal software package and it runs on Microsoft Windows 7.

11.4 Siting Requirements

The site must be level and far enough removed from buildings or structures that might have an impact on local winds.

11.5 Specifications

N/A

11.6 Theory of Operation

N/A

11.7 Calibration

The plane distances will be measured every four months and adjustments made as needed.

11.7.1 Theory

N/A

11.7.2 Procedures

N/A

12.0 History

N/A

13.0 User Manual

Video Disdrometer Manual − OU_V102.pdf

14.0 Routine Operation and Maintenance

Frequency: weekly

14.1 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 preventive maintenance (PM) activity.

14.2 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.

14.3 Disdrometer Maintenance

Keep sensor free of leaves and/or other debris.
Monitor the intensity of the illumination lamps and adjust as necessary to keep the intensity levels between 100 and 200 counts.

Checklist response

No problems noted.
Problem − Enter any applicable comments for this PM activity.

15.0 Citable References

Bringi, VN. 2011. Inter-Comparison and Reliability Study of the Next-Generation 2D-Video Disdrometer. U.S. National Aeronautics and Space Administration. Final Report NNX09AD72G.

Gunn, R, and GD Kinzer. 1949. “The terminal velocity of fall for water droplets in stagnant air.” *Journal of Meteorology* 6(4): 243-248, https://doi.org/10.1175/1520-0469(1949)006<0243:TTVOFF>2.0.CO;2

Thurai, M, WA Peterson, A Tokay, C Schultz, and P Gatlin. 2011. “Drop size distribution comparison between Parsivel and 2-D video disdrometers.” Advances in Geoscience 30: 3−9, https://doi.org/10.5194/adgeo-30-3-2011

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