U.S. DEPARTMENT OF ENERGY | Office of Science

DOE/SC-ARM-TR-221

Laser Disdrometer Quantities (LDQUANTS) and Video Disdrometer Quantities (VDISQUANTS) Value-Added Products Report

J Hardin
A Zhou

SE Giangrande

April 2020

ARM

DISCLAIMER

DOE/SC-ARM-TR-221

Laser Disdrometer Quantities (LDQUANTS) and Video Disdrometer Quantities (VDISQUANTS) Value-Added Products Report

J Hardin, Pacific Northwest National Laboratory
SE Giangrande, Brookhaven National Laboratory
A Zhou, Brookhaven National Laboratory

April 2020

Work supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

Acronyms and Abbreviations

2D	two-dimensional
ARM	Atmospheric Radiation Measurement
DSD	drop size distribution
GoAmazon	Green Ocean Amazon 2014/15
KDP	Specific Differential Phase
LDQUANTS	Laser Disdrometer Quantities Value-Added Product
lwc	liquid water content
VDISQUANTS	Video Disdrometer Quantities Value-Added Product
NetCDF	Network Common Data Form
NEXRAD	next-generation weather radar
VAP	value-added product
WACR	W-band ARM Cloud Radar

Contents

Figures

Tables

1.0 Introduction

Disdrometers are useful instruments that measure the distribution of raindrop sizes (drop size distribution: DSD) and the associated rainfall rates/accumulation as those raindrops fall to the ground. These DSDs are a quantity of interest to members of the modeler and observational communities. However, use of disdrometer data for model evaluation, radar monitoring, or other activities requires careful quality control and processing for key DSD properties of interest (e.g., the number concentration of drops) to ensure appropriate physical (scattering, fall speed) assumptions. The U.S. Department of Energy Atmospheric Radiation Measurement (ARM) Laser Disdrometer Quantities and Video Disdrometer Quantities Value-Added Product (LDQUANTS/VDISQUANTS VAP) uses standard methods from Tokay et al. (e.g., 2013, 2014) to filter drops with unrealistic fall speeds. Further, it estimates several microphysical/geophysical quantities of parameterized DSDs (gamma or exponential assumption type fitting methods) as in previous disdrometer studies and ARM long-term efforts (e.g., Testud et al. 2001, Giangrande et al. 2014, Thompson et al. 2015). Disdrometers are also beneficial for cross-checks with other instrumentation, including rain gauges and radars. To support research interests and related radar monitoring activities, this product calculates radar equivalent quantities, including dual polarization radar quantities (e.g., Z, Differential Reflectivity ZDR, etc.), using T-Matrix scattering and additional wavelength, temperature, and drop shape assumptions (e.g., Thurai et al. 2007).

All of these efforts allow disdrometer data sets to become more useful and easily handled by modeling and observational studies, or routine instrumentation checks.

2.0 Input Data

This product accepts "ld.b1" disdrometer data (or comparable laser/video disdrometer data sets). The VAP is created using the following inputs from the ld.b1 file:

Table 1. Input variables for LDQUANTS/VDISQUANTS.

ld.b1	
Name	**Long Name**
raw_spectrum	Raw drop size distribution
precip_rate	Precipitation intensity
class_size_width	Diameter dimension
fall_velocity_calculated	Fall speed rain drops

3.0 Methodology

This product performs quality control filtering, DSD parameter estimation, and radar scattering concepts. Quality control processing is based on techniques from Tokay et al. (2013, 2014) that restrict the DSD observations to drops that fall within 50% of terminal fall speed for that drop size (as from a Lhermitte (2002) fall speed approximation reference assumed for each estimated drop diameter). This process removes spurious drop measurements potentially caused by bouncing raindrops, insects, or other sources of contamination. Once the drop spectrum has been filtered, several useful geophysical quantities can be estimated, including the rainfall rate over the native sampling resolution (1-minute, temporal aggregations). The 1-minute aggregation window helps reduce the effects of outliers in the drop spectrum and reduce the noisiness of the data (total number of drops over that window is reported and can be used for additional filtering). This cleans up the drop spectrum and converts it into a series of DSD estimates for each time interval. The two-dimensional (2D) time series of DSDs will be reported in the output file.

From the cleaned-up DSD, this product then estimates DSD parametric fits to gamma, normalized gamma, and exponential distributions. This provides a time series of distribution parameters that can be directly compared to model outputs. The time series of these parameter fits will be recorded in the output file. This estimation uses method of moments where appropriate, and other community algorithms for some of the normalized gamma parameters.

The third component of this product is the estimation of radar equivalent quantities using T-Matrix scattering (e.g., Mishchenko et al. 1996). Polarimetric radar parameters including Z, ZDR, and Specific Differential Phase (KDP) are also estimated for all operational frequencies ARM uses, to include longer-wavelength, next-generation weather radars (NEXRADs; 10-cm wavelength) to W-Band radar options (e.g., W-band ARM Cloud Radar [WACR], 3-mm wavelength). Implementations of the algorithms are from the open source PyDSD library (Hardin 2017). These radar quantities support direct science, retrievals, and monitoring comparisons between ARM assets.

4.0 Output Data

This VAP outputs a daily NetCDF file. Table 2 lists the major output variables from the VAP.

Table 2. Major output variables from LDQUANTS/VDISQUANTS.

Variables for VAP	
Name	**Long Name**
reflectivity_factor_sband20c	Reflectivity factor s-band when temperature is 20c
reflectivity_factor_cband20c	Reflectivity factor c-band when temperature is 20c
reflectivity_factor_xband20c	Reflectivity factor x-band when temperature is 20c
reflectivity_factor_kaband20c	Reflectivity factor ka-band when temperature is 20c
reflectivity_factor_wband20c	Reflectivity factor w-band when temperature is 20c
differential_reflectivity_sband20c	Differential reflectivity s-band when temperature is 20c
differential_reflectivity_cband20c	Differential reflectivity c-band when temperature is 20c
differential_reflectivity_xband20c	Differential reflectivity x-band when temperature is 20c
differential_reflectivity_kaband20c	Differential reflectivity ka-band when temperature is 20c
differential_reflectivity_wband20c	Differential reflectivity w-band when temperature is 20c
specific_differential_phase_sband20c	Specific differential phase s-band when temperature is 20c
specific_differential_phase_cband20c	Specific differential phase c-band when temperature is 20c
specific_differential_phase_xband20c	Specific differential phase x-band when temperature is 20c
specific_differential_phase_kaband20c	Specific differential phase ka-band when temperature is 20c
specific_differential_phase_wband20c	Specific differential phase w-band when temperature is 20c
specific_attenuation_sband20c	Specific attenuation s-band when temperature is 20c
specific_attenuation_cband20c	Specific attenuation c-band when temperature is 20c
specific_attenuation_xband20c	Specific attenuation x-band when temperature is 20c
specific_attenuation_kaband20c	Specific attenuation ka-band when temperature is 20c
specific_attenuation_wband20c	Specific attenuation w-band when temperature is 20c
specific_ differential_attenuation_sband20c	Specific differential attenuation s-band when temperature is 20c

Variables for VAP	
Name	**Long Name**
specific_ differential_attenuation_cband20c	Specific differential attenuation c-band when temperature is 20c
specific_ differential_attenuation_xband20c	Specific differential attenuation x-band when temperature is 20c
specific_ differential_attenuation_kaband20c	Specific differential attenuation ka-band when temperature is 20c
specific_ differential_attenuation_wband20c	Specific differential attenuation w-band when temperature is 20c
mean_doppler_vel_sband20c	Mean Doppler velocity s-band when temperature is 20c
mean_doppler_vel_cband20c	Mean Doppler velocity c-band when temperature is 20c
mean_doppler_vel_xband20c	Mean Doppler velocity x-band when temperature is 20c
mean_doppler_vel_kaband20c	Mean Doppler velocity ka-band when temperature is 20c
mean_doppler_vel_wband20c	Mean Doppler velocity w-band when temperature is 20c
rain_rate	Instantaneous rainfall rate of water flux
gammapsd_slope	GammaPSD slope
gammapsd_shape	Shape parameter of modeled drop size distribution
num_concen	Intercept parameter of modeled drop size distribution
nor_num_concen	Normalized intercept parameter of a normalized Gaussian distribution
med_diameter	Median drop diameter
mass_weighted_mean_diameter	Mean drop diameter
lwc	Liquid water content
total_droplet_concentration	Total droplet concentration

5.0 Summary

This product is designed to encourage the use of disdrometer data sets by observational and model activities, as well as advanced infrastructure monitoring, uncertainty, and data quality activities from cross-comparisons with other ARM precipitation platforms. The primary scope of this product is to:

1. Provide a cleaned and filtered datastream from multiple ARM disdrometers.
2. Estimate commonly used physical parameters of the drop size distribution (DSD).
3. Calculate radar equivalent quantities such as the Radar Reflectivity Factor (Z).

6.0 Example Plots

Quicklook images are produced for each day of LDQUANTS/VDISQUANTS processing.

Figures 1−3 (below) present some sample outputs from LDQUANTS for the 15 October 2014 event from the Green Ocean Amazon (GoAmazon2014/15) campaign. In these panels, we show differential reflectivity ZDR, liquid water content (lwc), and specific attenuation (C-band, 20C) for the passage of a convective cell.

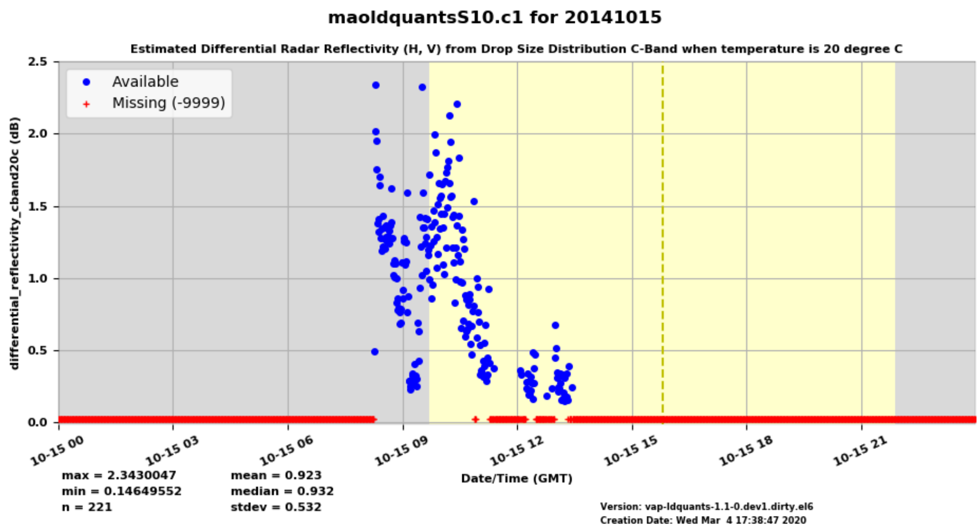

Figure 1. Quicklook image (differential_reflectivity_cband20c) produced by the LDQUANTS VAP for MAO-S10 on 20141015.

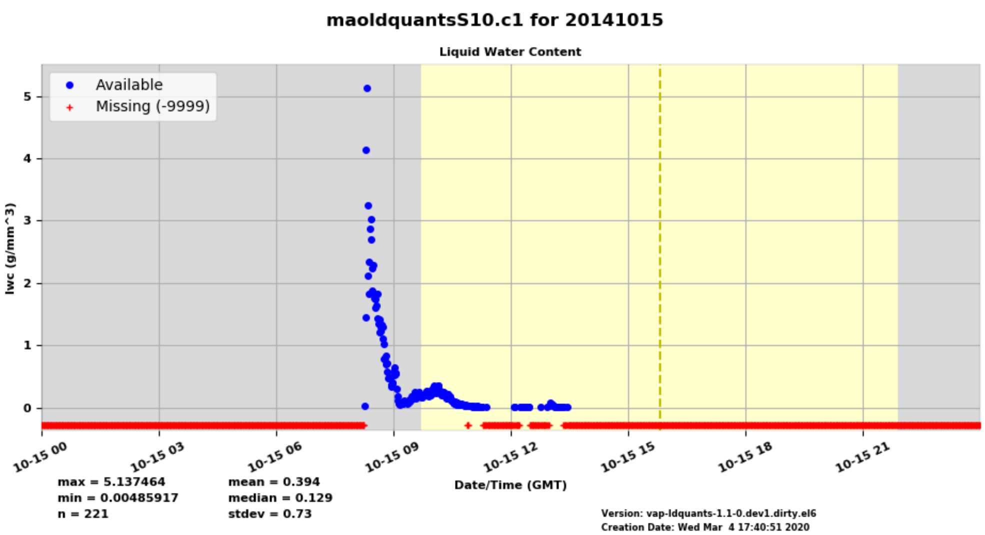

Figure 2. Quicklook image (lwc) produced by the LDQUANTS VAP for MAO-S10 on 20141015.

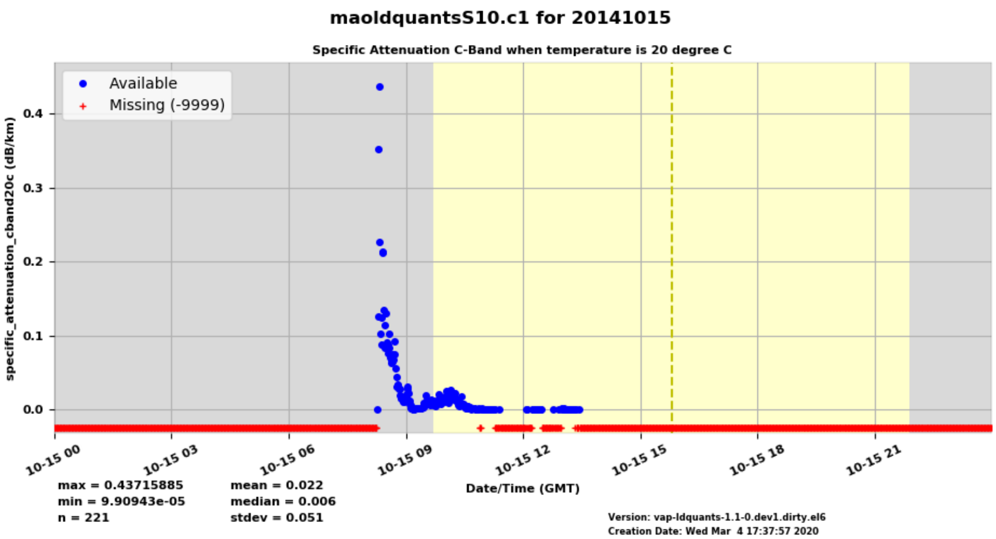

Figure 3. Quicklook image (specific_attenuation_cband20c) produced by the LDQUANTS VAP for MAO-S10 on 20141015.

7.0 References

Giangrande, SE, MJ Bartholomew, M Pope, S Collis, and MP Jensen. 2014. "A summary of precipitation characteristics from the 2006–11 northern Australian wet seasons as revealed by ARM disdrometer research facilities (Darwin, Australia)." *Journal of Applied Meteorology and Climatology* 53(5): 1213–1231, https://doi.org/10.1175/JAMC-D-13-0222.1

Hardin, JC. 2014. PyDisdrometer v1.0, http://doi.org/10.5281/zenodo.9991

Lhermitte, RM. 2002. *Centimeter and millimeter wavelength radars in meteorology*, p. 550. Lhermitte Publications.

Mishchenko, MI, LD Travis, and DW Mackowski. 1996. "T-matrix computations of light scattering by nonspherical particles: A review." *Journal of Quantitative Spectroscopy and Radiative Transfer* 55(5):535−575, https://doi.org/10.1016/0022-4073(96)00002-7

Testud, J, S Oury, RA Black, P Amayenc, and X Dou. 2001. "The concept of "normalized" distribution to describe raindrop spectra: A tool for cloud physics and cloud remote sensing." *Journal of Applied Meteorology and Climatology* 40(6): 1118–1140, https://doi.org/10.1175/1520-0450(2001)040<1118:TCONDT>2.0.CO;2

Thompson, JE, SA Rutledge, B Dolan, and M Thurai. 2015. "Drop size distributions and radar observations of convective and stratiform rain over the equatorial Indian and west Pacific Oceans." *Journal of the Atmospheric Sciences* 72(11): 4091–4125, https://doi.org/10.1175/JAS-D-14-0206.1

Thurai, M, GJ Huang, VN Bringi, WL Randeu, and M Schönhuber. 2007. "Drop shapes, model comparisons, and calculations of polarimetric radar parameters in rain." *Journal of Atmospheric and Oceanic Technology* 24(6): 1019–1032, https://doi.org/10.1175/JTECH2051.1

Tokay, A, WA Petersen, P Gatlin, and M Wingo. 2013. “Comparison of raindrop size distribution measurements by collocated disdrometers.” *Journal of Atmospheric and Oceanic Technology* 30(8): 1672–1690, https://doi.org/10.1175/JTECH-D-12-00163.1

Tokay, A, RJ Roche, and PG Bashor. 2014. “An experimental study of spatial variability of rainfall.” *Journal of Hydrometeorology* 15(2): 801–812, https://doi.org/10.1175/JHM-D-13-031.1

ARM

www.arm.gov

U.S. DEPARTMENT OF
ENERGY

Office of Science