

ATMO 689

POLARIMETRIC RADAR METEOROLOGY

Homework #1

Due: 30 September 2004

The Joss-Waldvogel (J-W) disdrometer (<http://www.distromet.com/default.htm> and pictured below in Fig. 1) for raindrops is an instrument for measuring raindrop size distributions continuously and automatically.



Fig. 1. Joss- Waldvogel (J-W) disdrometer signal processor/storage (left) and measuring unit (right).

It was developed because statistically meaningful samples of raindrops could not be measured previously without a prohibitive amount of work. The J-W instrument transforms the vertical momentum of an impacting drop into an electric pulse whose amplitude is a function of the drop diameter. A conventional pulse height analysis yields the size distribution of raindrops in 20 discrete bins.

The TRMM-LBA (Tropical Rainfall Measuring Mission – Large-Scale Biosphere Atmosphere) Mesoscale Experiment was conducted in Rondonia, Brazil from 1 Jan – 28 Feb 1999. One of the goals of this experiment was to accurately describe the drop size distribution (DSD) and measure rain rates in tropical precipitation systems over the Amazon using disdrometers and research radars (http://radarmet.atmos.colostate.edu/trmm_lba/).

Discrete 1-minute average rain drop size distribution (DSD) data in 20 size bins measured by a J-W disdrometer are given in Table 1 below for 19 minutes of a moderate-to-heavy rain event over the Ji-Parana airport on 1-22-99 from 1904 to 1922 UTC. The bin center diameter (mm) and bin spacing (mm) for each of the 20 bins are provided in the 1st and 2nd rows respectively. Low-level (1.1° elevation angle) surveillance scans of measured radar reflectivity (Z, dBZ) from the SPOL radar for 1909 and 1919 UTC are presented in Fig. 2 for comparison.

- a) Using the following definitions of radar reflectivity (z , $\text{mm}^6 \text{m}^{-3}$) and rain rate (R, mm h^{-1}) for discrete data,

$$z = \sum_{i=1}^M N(D_i) \cdot D_i^6 \cdot \Delta D_i$$

where i is the bin number, $N(D_i)$ is the size distribution per D_i bin, M is the total number of bins, D_i is the i^{th} diameter size, and ΔD_i is the i^{th} bin size and

$$R = \sum_{i=1}^M V(D_i) \cdot N(D_i) \cdot v(D_i) \cdot \Delta D_i$$

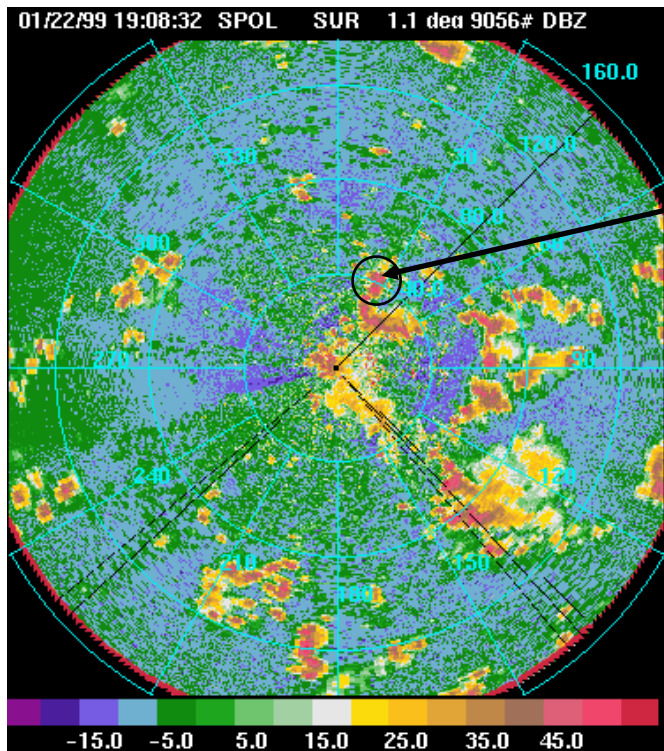
where $V(D_i)$ is the volume of the i^{th} drop of size D_i , and $v(D_i) = 386.6 \cdot D_i^{0.67} [\text{m s}^{-1}]$ is the terminal velocity of the rain drop as a function of size D_i [*Note*: D is in meters (m) for this empirical $v(D)$ equation],

- 1) calculate the radar reflectivity (factor) (z , $\text{mm}^6 \text{m}^{-3}$) for each of the nineteen 1-minute averages of the DSD provided in Table 1 below. Also provide the answer in dBZ (Z). Compare your disdrometer-derived estimates of Z (dBZ) at 1909 and 1919 UTC to the values of reflectivity (Z, dBZ) measured by the S-POL radar at the same times (Figs. 2a,b respectively). (*Note*: rough “by eye” comparison with Figs 2a,b). [*Recall*: $Z(\text{dBZ}) = 10 \cdot \text{LOG}_{10}(z)$]
 - 2) calculate the rain rate (R, mm h^{-1}) for each of the nineteen 1-minute averages of the DSD provided in Table 1 below.
- b) Plot R (rain rate) versus z ($\text{mm}^6 \text{m}^{-3}$) for the 19 points [i.e., treat z as the independent variable and R as the dependent variable; plot R along the ordinate (or y-axis) and z along the abscissa (or x-axis)].
- c) Regress a *power law* relationship between z and R of the form $R = \mathbf{c} \cdot z^{\mathbf{d}}$ where z is in $\text{mm}^6 \text{m}^{-3}$ and R is in mm h^{-1} . Traditionally (even though z is measured), radar meteorologists often express this equation in the form $z = \mathbf{a} \cdot R^{\mathbf{b}}$ (i.e., the so called z-R relationship). After deriving (**c,d**) through linear regression, also calculate the (**a,b**) coefficients for comparison with traditional z-R relations. Plot R versus z using the regressed power law curve (**c,d**) for this sample of TRMM-LBA J-W data on top of the 19 observed points. Provide the coefficients (**c,d**) and the correlation coefficient of the linear regression on your plot.

- d) As a radar meteorologist, you might use the regressed z-R from c) with measured reflectivity (z) from the *S-POL radar* (e.g., Figs. 2a,b) to estimate rainfall over a much larger area of the Amazon jungle than could be practically covered by rain gauges. Compare the regressed power law function from c) to the plotted points in b). Do all of the z-R points fall on the regressed line? What is the scatter? What is the implication for the *radar* estimation of rainfall using a z-R technique?
- e) What if you did not have disdrometer data from which to derive a tuned or custom z-R relation? The operational WSR-88D currently uses one of two prescribed z-R relations. As a default z-R relation, the WSR-88D uses $z = 300 \bullet R^{1.4}$. In those situations where the forecaster believes the convection to be tropical, the tropical WSR-88D z-R is used: $z = 250 \bullet R^{1.2}$. Compare the default WSR-88D, the tropical WSR-88D, and your derived TRMM-LBA z-R by placing the three curves together in a single plot. If the TRMM-LBA z-R is the “true” relation, then what is the implication for the WSR-88D *radar* estimation of rainfall using a z-R technique?

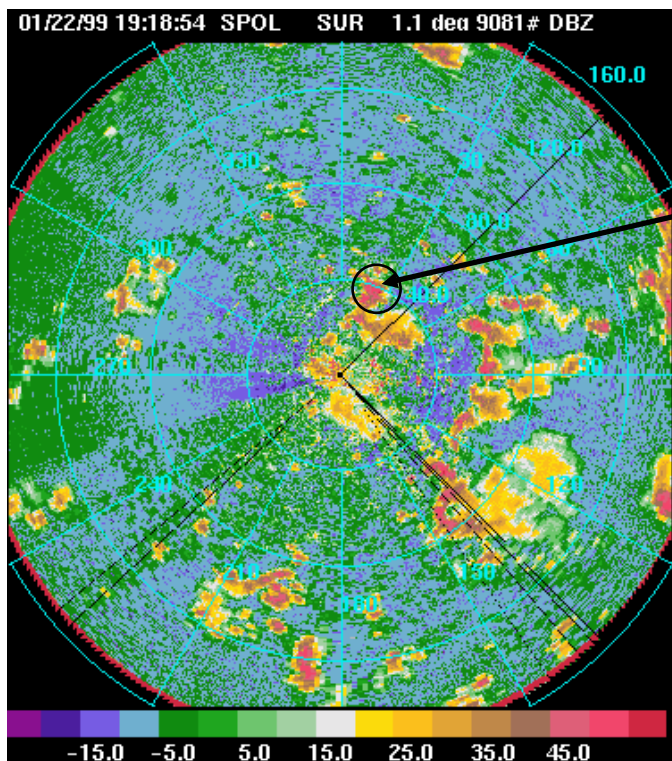
Table 1. Discrete 1-minute average rain drop size distribution (DSD) data in 20 size bins measured by a J-W disdrometer that was deployed over the Amazon (southwest Brazil) during the TRMM-LBA mesoscale field experiment. The processed (i.e., corrected for instrument artifacts) data below is from 19 minutes of a heavy rain event over the Ji-Parana airport on 1-22-99 from 1904 to 1922 UTC.

Discrete J-W Bin #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Bin Center Diameter (D) [mm]	0.35	0.45	0.55	0.65	0.75	0.90	1.10	1.30	1.50	1.70	1.95	2.25	2.55	2.85	3.15	3.50	3.90	4.30	4.75	5.25
Bin Diameter spacing (ΔD) [mm]	0.10	0.10	0.10	0.10	0.10	0.20	0.20	0.20	0.20	0.20	0.30	0.30	0.30	0.30	0.30	0.40	0.40	0.40	0.50	0.50
N(D) [$m^{-3} mm^{-1}$] Bin Concentration																				
1904 UTC	0.00	0.00	0.00	0.00	13.80	27.80	103.00	110.00	89.50	101.00	109.00	66.70	53.00	21.50	24.70	10.90	0.96	2.82	0.00	0.00
1905 UTC	0.00	0.00	0.00	0.00	57.30	165.00	354.00	258.00	180.00	129.00	88.50	85.50	22.60	7.16	8.25	3.98	3.85	3.76	0.00	0.00
1906 UTC	0.00	0.00	0.00	53.70	175.00	264.00	464.00	300.00	177.00	109.00	87.10	43.80	24.20	12.90	11.00	10.90	12.50	1.88	0.00	0.00
1907 UTC	0.00	0.00	0.00	14.60	12.30	65.60	296.00	152.00	34.60	28.70	31.40	14.50	6.03	10.00	4.13	7.95	3.85	0.94	1.47	0.00
1908 UTC	0.00	0.00	19.00	15.30	0.00	110.00	279.00	170.00	76.70	37.80	30.00	6.48	19.70	18.70	13.80	12.90	7.70	2.82	0.74	0.00
1909 UTC	0.00	0.00	0.00	15.40	13.00	85.00	104.00	40.70	39.30	23.80	39.50	47.50	36.60	41.80	20.70	10.90	12.50	3.76	0.74	0.00
1910 UTC	0.00	0.00	0.00	0.00	0.00	46.50	80.50	29.10	32.30	29.40	40.90	50.40	28.80	20.10	24.80	7.95	7.70	0.94	1.47	0.00
1911 UTC	0.00	0.00	0.00	0.00	13.70	71.90	178.00	83.20	43.30	63.10	79.50	47.60	41.20	31.80	31.80	14.90	16.40	3.75	0.00	0.00
1912 UTC	0.00	0.00	0.00	0.00	0.00	13.20	179.00	177.00	152.00	135.00	140.00	117.00	90.20	65.70	59.60	29.90	21.20	7.50	3.68	0.72
1913 UTC	0.00	0.00	0.00	0.00	0.00	20.20	73.40	125.00	133.00	170.00	152.00	130.00	78.70	42.80	58.80	28.10	37.80	24.40	10.30	0.00
1914 UTC	0.00	0.00	0.00	0.00	0.00	14.30	49.40	125.00	163.00	206.00	214.00	198.00	109.00	93.60	66.50	33.80	19.30	6.56	1.47	0.00
1915 UTC	0.00	0.00	0.00	0.00	0.00	75.10	209.00	280.00	258.00	264.00	301.00	199.00	112.00	40.80	73.30	31.80	19.30	4.68	0.74	0.00
1916 UTC	0.00	0.00	24.60	0.00	77.30	145.00	180.00	243.00	183.00	190.00	199.00	117.00	45.20	24.30	8.24	4.96	0.96	0.94	0.00	0.00
1917 UTC	0.00	0.00	39.30	15.70	65.50	122.00	209.00	192.00	115.00	121.00	78.60	43.20	12.00	5.71	4.12	0.99	0.00	0.00	0.00	0.00
1918 UTC	0.00	0.00	0.00	15.20	38.30	139.00	275.00	237.00	160.00	111.00	36.30	12.70	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1919 UTC	0.00	0.00	0.00	15.60	39.10	68.60	196.00	163.00	127.00	124.00	95.90	38.30	10.50	4.28	2.74	0.00	0.00	0.00	0.00	0.00
1920 UTC	0.00	0.00	0.00	116.00	97.80	85.10	156.00	109.00	71.90	76.90	71.00	19.10	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1921 UTC	0.00	0.00	0.00	0.00	23.50	29.20	44.30	93.90	121.00	59.50	27.60	7.96	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1922 UTC	0.00	0.00	0.00	13.40	45.80	76.20	71.10	68.70	67.70	22.60	13.80	6.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00



a.

Convective cell producing moderate rain over Ji-Parana, Brazil airport at 1909



b.

Convective cell producing light rain over Ji-Parana, Brazil airport at 1919

Fig. 2. Low-level (elevation angle = 1.1°) surveillance scan of reflectivity (Z, dBZ) from the NCAR (National Center for Atmospheric Research) S-POL (S-band Polarimetric) radar at a) 1909 UTC and (b) 1919 UTC on 22 Jan 1999. The Ji-Parana airport (e.g., disdrometer) is located at a range of 43 km and an azimuth of 20° from the S-POL radar. A circle highlights the storm responsible for the rain and an arrow points to the location of the disdrometer.