Profiler Data Sets for the NASA PMM Community

1. Background

In support of NASA PMM, observations collected near Darwin, Australia, have been processed and data sets are being provided to the NASA PMM community to help validate and improved satellite retrieval algorithms and cloud resolving models.

The data sets are derived from surface rain gauges, a disdrometer, and vertical pointing profilers deployed at the Australian Bureau of Meteorology Research Centre (BMRC) wind profiler site near Darwin, Australia during the Tropical Western Pacific – International Cloud Experiment (TWP-ICE).

2. Overview of Data Sets

The data sets were collected from instruments installed at the BMRC wind profiler site (12.443 S, 130.956 E) located 8 km east of the ARM climate observation site (12.425 S, 130.981 E). The location of the BMRC wind profiler site is shown in Google map of Darwin Figure 1.
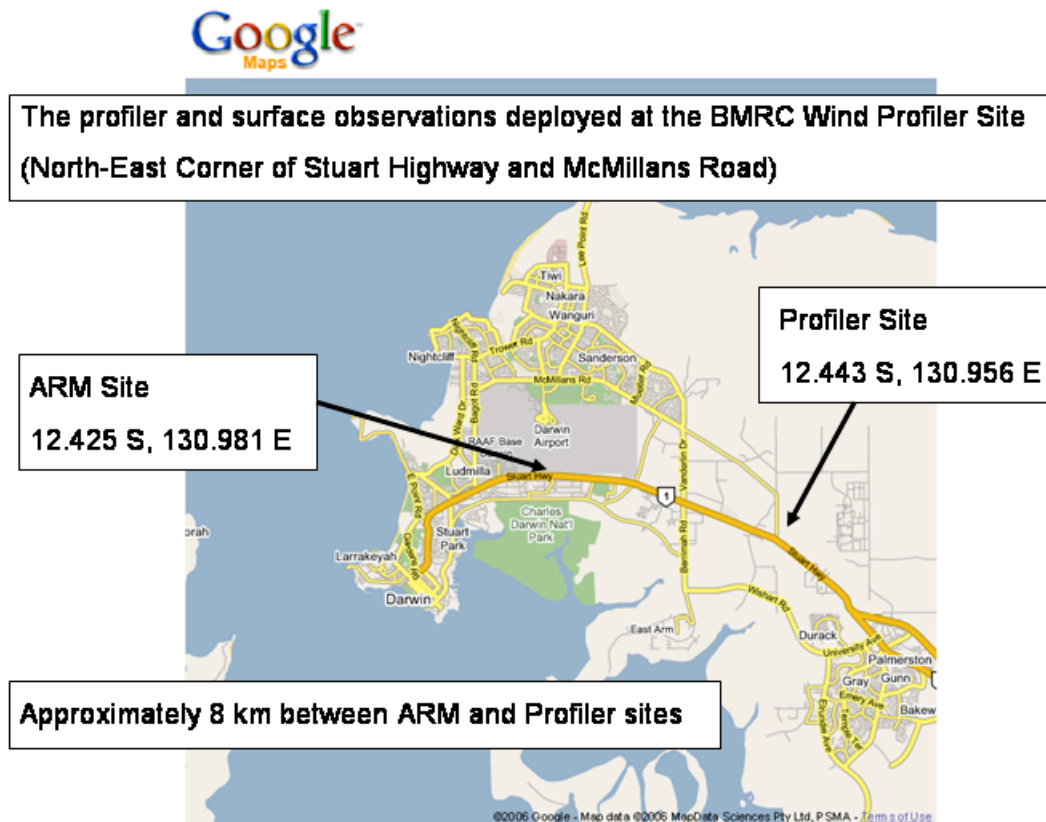

Figure 1. Map showing location of ARM site and BMRC wind profiler site.

During the TWP-ICE field campaign, the following instruments were operating at the BMRC wind profiler site:

- • 2 Tipping bucket rain gauges (NOAA)
- • 1 Joss-Waldvogel Disdrometer (JWD) (second unit did not function properly) (NOAA)
- • 1 Vertically pointing S-band profiler (2835-MHz) (NOAA)
- • 1 UHF wind profiler (920-MHz) (BMRC)
- • 1 VHF wind profiler (50-MHz) (BMRC)

The NOAA instruments were installed on 9 November 2005 and were removed on 10 June 2006. Data is available from all instruments during this period expect from the S-band profiler during 6 December through 6 January when a software error prevented the S-band profiler data from being collected. The instruments are shown in Figures 2 and 3.
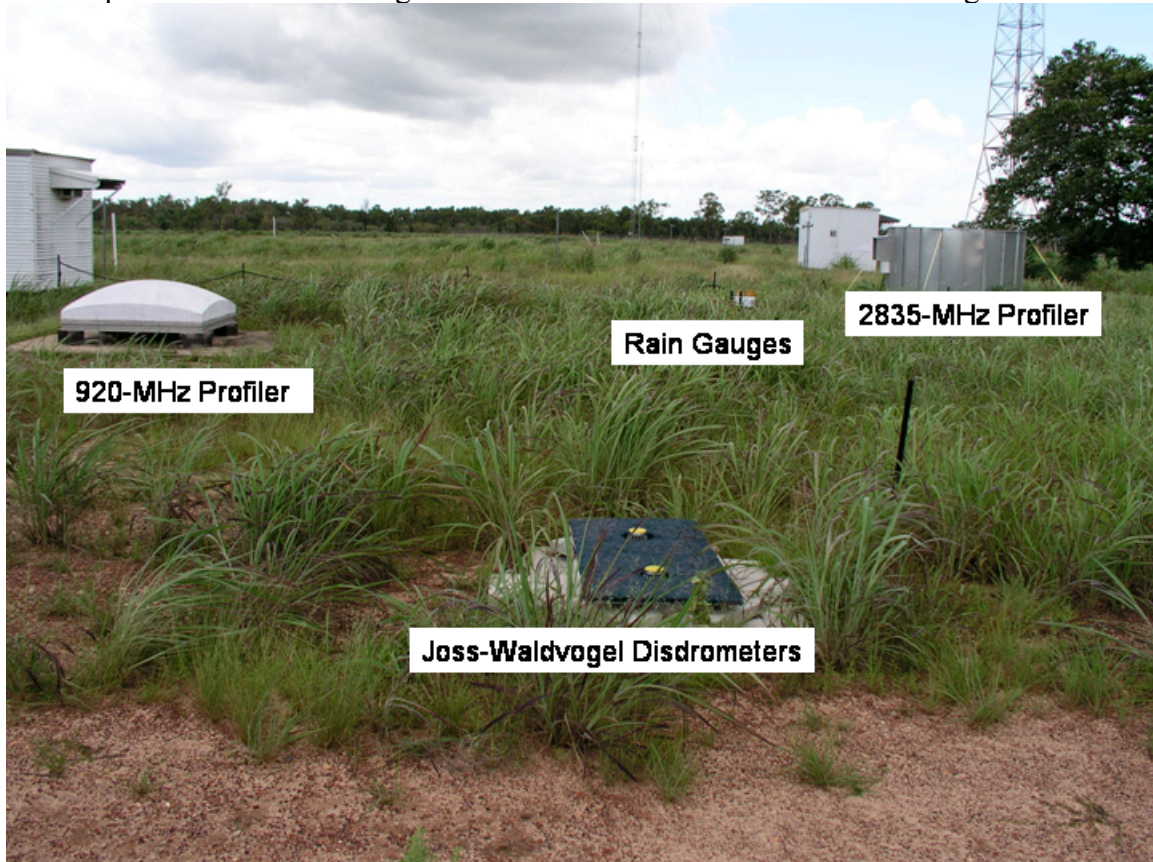

Figure 2. This photo shows the 920-MHz wind profiler, surface Joss-Waldvogel disdrometers, rain gauges, and 2835-MHz (S-band) profiler as they were deployed during TWP-ICE.
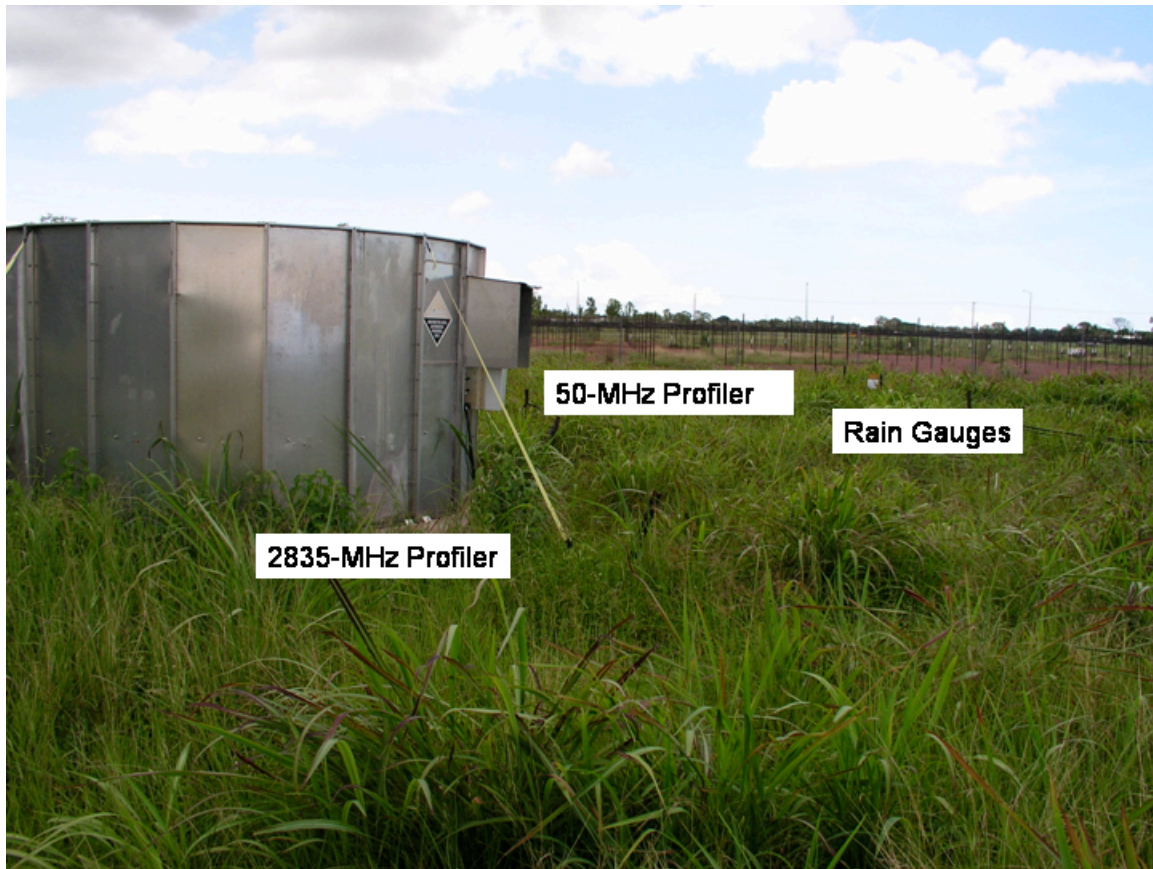
Figure 3. This photo shows the 2835-MHz (S-band) profiler, 50-MHz wind profiler, and surface rain gauges as they were deployed during TWP-ICE.

The following data sets are available to the NASA PMM community:
- Tipping bucket rain gauge data (two rain gauges)
- Joss-Waldvogel Disdrometer
    - Dead-time corrected raindrop count
    - Number concentration N(D)
    - Reflectiviy, rain rate, liquid water content, mass-weighted mean diameter, and normalized scale parameter (Nw)
- 920-MHz wind profiler calibrated moments
    - Reflectivity, mean Doppler velocity, and Doppler velocity variance
- 920-MHz wind profiler derived Gamma Function DSD (1.5 to 4 km)
    - Scale parameter, Median diameter, and shape parameter
    - Reflectivity, rain rate, liquid water content, and vertical air motion
- 920-MHz wind profiler derived mean ensemble DSD (1.5 to 4 km)
    - ensemble mean scale parameter and ensemble mean median diameter
    - ensemble mean reflectivity, rain rate, liquid water content
    - vertical air motion
    - standard deviation of ensemble mean scale parameter, mean median diameter, reflectivity, rain rate, and liquid water content
- 920-MHz wind profiler derived ensemble DSDs (1.5 to 4 km)

o   DSD parameters from each of the 42 different models that comprise the
    ensemble

3. Rain Gauges

Two tipping bucket rain gauges operated from 9 November 2005 through 10 June 2006.
The rain gauges counted the number of tips that occurred in each 10 second interval with
each tip corresponding to 1/100 of an inch of rain. The 10-second recorded time stamp
corresponds to the end of the accumulation period. The rain gauge clock is the same as
the S-band profiler clock. There was also a pressure sensor installed with the rain gauges.

3.1 ASCII Data Format

The tipping bucket rain gauge data are stored in daily files following the naming
convention: dar_raingauge_yyyy_ddd.dat, where yyyy is the year and ddd is the day of
year. Each daily file contains 8640 rows (24*60*6) and bad or missing data values are
indicated with a value of -99.9.There are 12 columns in each data file with each column
having the following variable:

Column	Description
1	Year
2	Day of year
3	Month
4	Day of month
5	Hour
6	Minute
7	Second (end of accumulation period)
8	Precipitation unit #1 (1/100 of an inch)
9	Precipitation unit #2 (1/100 of an inch)
10	Pressure (hPA)
11	Battery Voltage (Volts)
12	Temperature inside shed (degrees C)

3.2 Daily Images

Daily images in PNG format were generated to show the 10 second surface pressure, 1-
minute rain rate, and the rain accumulation throughout the day. The filename follows the
format dar_raingauge_yyyy_ddd.png, where yyyy is the year and ddd is the day of year.
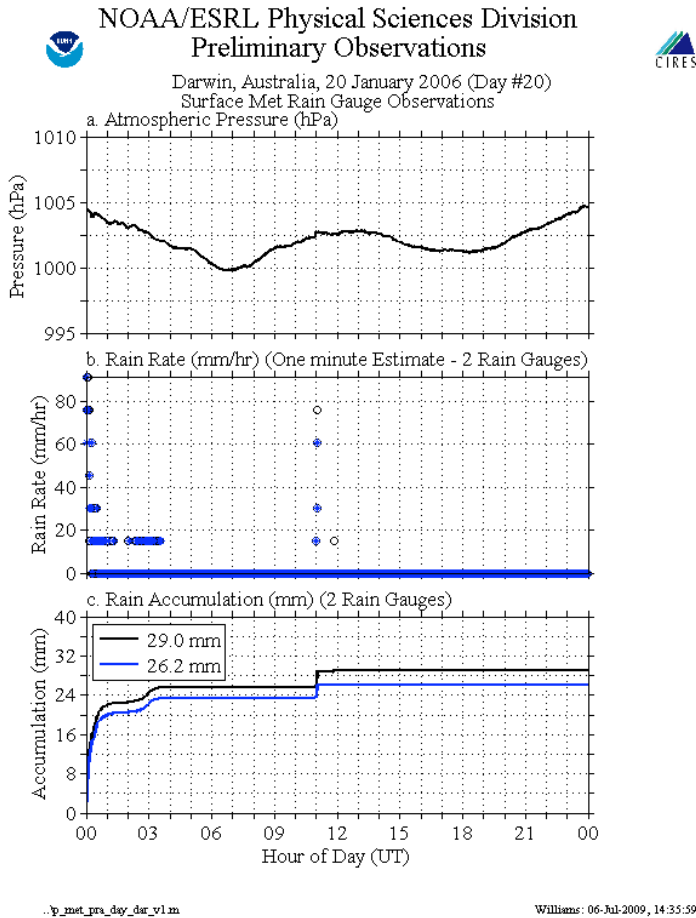An example image is shown in Figure 4.

Figure 4. Example of surface rain gauge day plot.

4. Joss-Waldvogel Disdrometer

Even though two Joss-Waldvogel Disdrometers (JWDs) were installed at the BMRC wind profiler site, only one unit produced usable data. The JWD was operational from 9 November 2005 through 10 June 2006.

The original JWD data were collected at the full 127 diameter channels and with a 10 second dwell time. These high resolution data were reduced to the standard 20 diameter channels and to a 1-minute resolution. A dead-time correction (Sheppard and Joe 1994; Sauvageot and Lacaux 1995) was applied to the raindrop counts. The data products are provided using the dead-time corrected raindrop counts and 60 second dwell time:
- Number of raindrops in each raindrop diameter size
- Number concentration in each raindrop diameter size
- Moments of reflectivity, rain rate, liquid water content, mass-weighted mean diameter, and normalized scale parameter (Nw)

The following constant values are also provided and used in processing the raw observations:

- Standard diameter channels (20 raindrop sizes) (file Dstd.dat)\
- Width of each diameter channel (file dDstd.dat)
- Terminal fall speed for each diameter, V=0.65 – 10.3exp(0.6D) (file velocity.dat)
- Sample volume for each diameter, (Surface area)(Dwell Time)(Velocity) (file Volume.dat)

4.1 ASCII Data Format

The ASCII data files are day files with 1-minute resolution and contain 1440 rows. Bad or missing data values are indicated with a value of -99.9.

4.1.1 Number of Raindrops in each Diameter Size

The dead-time corrected drop counts for each diameter channel are provided in the files named: dar_jwd_dtc_cnt_yyyy_ddd.dat, where
- dar = Darwin
- jwd = Joss-Waldvogel Disdrometer
- dtc = dead-time corrected
- cnt = number count
- yyyy = year
- ddd = day of year

There are 1440 rows and 20 columns in each day file. Each column corresponds to the raindrop diameter specified in Dstd.dat.

4.1.2 Number Concentration

The dead-time corrected Number Concentration each diameter channel are provided in the files named: dar_jwd_dtc_ND_yyyy_ddd.dat.

- dar = Darwin
- jwd = Joss-Waldvogel Disdrometer
- dtc = dead-time corrected
- ND = N(D) = Number concentration, units of (#/m^3) for each diameter size (mm)
- yyyy = year
- ddd = day of year

There are 1440 rows and 20 columns in each day file. Each column corresponds to the raindrop diameter specified in Dstd.dat.

4.1.3 Moments and DSD Parameters

The dead-time corrected N(D) is used to estimate the moments of the DSD and are provided in the files named: dar_jwd_dtc_mom_yyyy_ddd.dat

where
- dar = Darwin
- jwd = Joss-Waldvogel Disdrometer
- dtc = dead-time corrected
- mom = moments

- yyyy = year
- ddd = day of year

There are 1440 rows and 15 columns in each data file. The variable in each column is:

Column   *Description*
1   year
2   day of year
3   hour
4   minute
5   Nt = Total number of drops in distribution
6   Reflectivity (dBZ)
7   Rain rate (mm/hr)
8   Liquid Water Content (g/m^3)
9   Dm = Mass-weighted mean diameter (mm)
10   Nw = Normalized Scale Parameter (mm^-1 /m^3)
11   Variance estimate of Z, var{Z} in (mm^6/m^3)^2
12   Variance estimate of R, var{R} in (mm/hr)^2
13   Variance estimate of LWC, var{LWC} in (g/m^3)^2
14   Variance estimate of Dm, var{Dm} in (mm)^2
15   Variance estimate of Nw, var{Nw} in (mm^-1 /m^3)^2

The time expressed in this file also corresponds to the time in the raindrop count and number concentration data files. Bad or missing data values are indicated with a value of -99.9.

4.2 Daily Images

Daily images in PNG format were generated to show the minute Joss-Waldvogel Disdrometer (JWD) estimated reflectivity, rain rate, and number concentration N(D). The filename follows the other disdrometer filename format with dar_jwd_dtc_day_yyyy_ddd.png, where yyyy is the year and ddd is the day of year. An example image is shown in Figure 5.
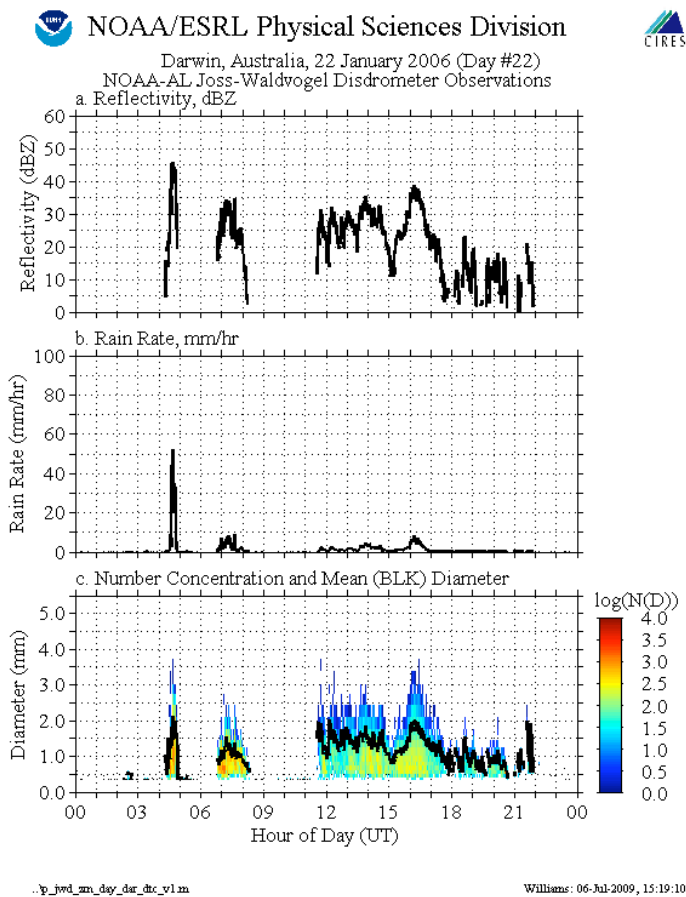
Figure 5. Example of Joss-Waldvogel disdrometer day plot.

5. 920-MHz Wind Profiler Calibrated Moments

The 920-MHz wind profiler operates in the Doppler Beam Swinging (DBS) mode and alternates the position of the radar beam from the vertical, East, and North positions. When the beam is pointed in the vertical direction, the wind profiler moments at each range gate provides information on the vertical structure of the precipitation as it passes directly over the profiler site. The observed Doppler velocity power spectra were calibrated to the surface disdrometer reflectivity.

The three moments of the Doppler velocity power spectrum represent the reflectivity, the mean reflectivity-weighted Doppler velocity, and the reflectivity-weighted Doppler velocity variance. If $S(v_i)$ (mm^6 m^{-3} (m s^{-1})$^{-1}$) is the calibrated Doppler velocity reflectivity spectral density at each Doppler velocity channel v_i, then the reflectivity is given by

$$z = \sum_i S(v_i)dV \qquad\qquad (\text{mm}^6\text{ m}^{-3}) \qquad\qquad (1)$$

where only the values of $S(v_i)$ greater than the noise are used in the summation, dV is the width of each Doppler velocity channel, and the reflectivity is expressed in decibel units (dBZ) using $Z = 10\log(z)$. The reflectivity-weighted mean Doppler velocity is given by

$$\langle V \rangle = \frac{\sum_i S(v_i)v_i dV}{\sum_i S(v_i)dV} \qquad\qquad (\text{m s}^{-1}) \qquad\qquad (2)$$

and the reflectivity-weighted Doppler velocity variance is given by

$$\sigma_V^2 = \frac{\sum_i (v_i - \langle V \rangle)^2 S(v_i)dV}{\sum_i S(v_i)dV} \qquad\qquad (\text{m}^2\text{ s}^{-2}). \qquad\qquad (3)$$

Note that the velocity variance is related to the spectrum width which is defined as $2\sigma_V$. If there wasn't any vertical air motion, the reflectivity-weighted mean Doppler velocity would be equal to the reflectivity-weighted mean terminal fall speed of the hydrometeor distribution $\langle V_{\text{terminal}} \rangle$ and is estimated using

$$\langle V_{\text{terminal}} \rangle = \frac{\sum_j N(D_j)D_j^6 V_{\text{terminal}}(D_j)dD_j}{\sum_j N(D_j)D_j^6 dD_j} \qquad\qquad (\text{m s}^{-1}) \qquad\qquad (4)$$

where D_j are the raindrop diameters sizes, dD_j are the raindrop diameter channel widths, $N(D_j)$ is the number concentration, and $V_{\text{terminal}}(D_j)$ is the terminal fall speed of a raindrop with diameter D_j. Taking into account the vertical air motion ω, $\langle V \rangle$ and $\langle V_{\text{terminal}} \rangle$ are related using

$$\langle V \rangle = \langle V_{\text{terminal}} \rangle - \omega \qquad\qquad (5)$$

where ω is defined as having positive values with upward motion. Thus, $\langle V \rangle = \langle V_{\text{terminal}} \rangle$ when $\omega = 0$ and $\langle V \rangle$ follows the Doppler velocity convention with positive values approaching the observer (in this case, the observer is on the ground looking upward).

In this data set, no attempt is made to estimate the vertical air motion ω or the reflectivity-weighted mean terminal fall speed of the hydrometeor distribution $\langle V_{\text{terminal}} \rangle$. The data files are the best attempt to estimate equations (1), (2), and (3) from the radar Doppler velocity spectra.

5.1 ASCII Data Format

The 920-MHz profiler moments are saved in hourly ASCII data files. The filenames follow this naming convention: dar920cal_vert_YYYY_DDD_hrHH.dat.
Where:
- dar = Darwin
- 920 = 920 MHz profiler
- cal = calibrated to Joss-Waldvogel Disdrometer

- vert = vertical beam
- YYYY = year
- DDD = day of year
- hr = hour
- HH = hour of day

The 920-MHz profiler moments are estimated from 45 second dwell periods. The profiler is configured to observe in the vertical beam direction at the start of every minute and dwell for 45 seconds. The profiler then observes in either the North or East beam for 15 seconds. Then the profiler repeats this pattern indefinitely alternating between the North and East beams. In the following data files, only the data from the vertical beam are provided. The time stamp the data file corresponds to the beginning of the dwell period.

The 920-MHz profiler moments are in sequential format. Each row corresponds to a particular pixel in the time-height plane. Each column corresponds to a particular variable:

Column	Description
1	year
2	day of year
3	month number
4	day of month
5	hour
6	minute
7	second
8	dayofyear.fraction of day
9	height above Mean Sea Level (MSL) (m)
10	number of profiles in minute
11	Reflectivity (dBZ)
12	Doppler Velocity, downward is positive (m/s)
13	Doppler velocity variance ($m^2 \, s^{-2}$)

The ASCII numbers are expressed in exponential notation using the format: 1.2345678e+123. The sign of the exponent could be either a '+' or '-'. There are two spaces between each number, but one space is used for the '-' symbol with negative numbers.

If the power return is below the level of detectability, the moments are not generated and the bad or missing data values are indicated with a value of -99.9 (-9.9000000e+001).

Data from all range gates are saved to the hourly data file. There are 166 range gates in each profile. Therefore, there are 60*166 rows in each hourly data file. In all data files, the data for minute 1 is missing and is set to the bad data flag.

5.2 Daily Images

Hourly images of the 920-MHz profiler moments of reflectivity, mean Doppler velocity, and Doppler velocity variance were generated from the hourly ASCII data files. The filename for the hourly images follows this format:
p_dar920_ZVV_YYYY_DDD_HH_v1.tif

where
- p_dar920 = plot of Darwin 920 MHz profiler
- ZVV = 3-panel plot of Reflectivity, mean Doppler velocity, and velocity variance
- YYYY = Year
- DDD = Day of year
- HH = hour of day
- v1.tif = version 1, tif format

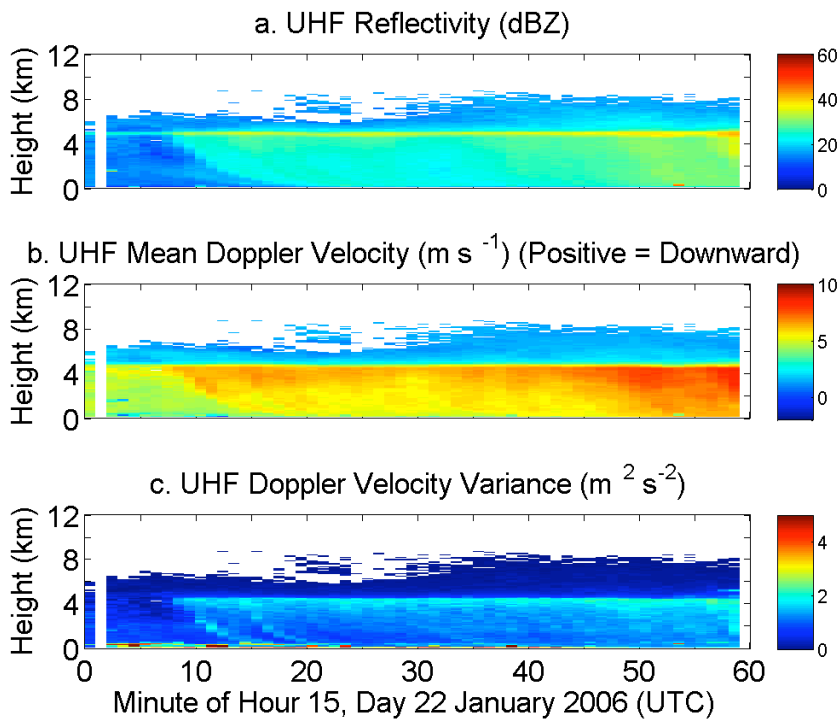An example image is shown in Figure 6.

Figure 6. An example image showing an hour's worth of 1-minute estimates of the 920-MHz profiler reflectivity, mean Doppler velocity, and velocity variance.

6. Gamma Function DSDs

The 50-MHz and 920-MHz profiler spectra were analyzed to estimate the raindrop size distribution (DSD) from 1.5 to 4.0 km directly above the profiler site. The retrieval method is described in detail in Williams and Gage (2009) (Ann. Geophys., 27, 555-567. 2009 www.ann-geophys.net/27/555/2009/). Basically, the retrieval method estimates the DSD at each range gate using 42 different models. One of those models assumes the raindrop size distribution has a Gamma functional form and the retrieved parameters are provided in hourly ASCII data files.

The gamma function DSD is assumed to have a modified Gamma functional form that can be described using equations (7.62a) and (7.62b) of Bringi and Chandrasekar (2001)

$$N(D) = N_w f(\mu) \left(\frac{D}{D_0} \right)^{\mu} \exp\left[-(3.67 + \mu) \frac{D}{D_0} \right] \tag{6}$$

with

$$f(\mu) = \frac{6}{(3.67)^4} \frac{(3.67 + \mu)^{\mu+4}}{\Gamma(\mu + 4)} \tag{7}$$

where the normalized scale parameter is given by

$$N_w = \frac{(3.67)^4}{\pi \rho_w} \left(\frac{10^3 W}{D_0^4} \right) \tag{8}$$

and W is the liquid water content of the raindrop size distribution, ρ_w is the density of water, D_0 is the mass-weighted mean diameter of the raindrop size distribution, and μ is the shape parameter.

For this particular hourly ASCII data set, the cost function minimized the squared difference between the observed and modeled spectra (χ^2 error), and the spectrum broadening was accounted for using the convolution method. These cost functions and numerical processing methods are described in detail in Williams and Gage (2009).

The rain rate is calculated using three different formulas. The first formula assumes the raindrops are falling at their surface terminal fall speed. The second formula assumes the raindrops are falling at their air density adjusted terminal fall speed, which increases with altitude. And the third formula is a mass flux calculation and incorporates the vertical air motion. If the raindrops are in an updraft, some smaller raindrops are moving upward and the downward mass flux is less than if the vertical air motion is ignored (as in the first two rain rate estimates). It is possible for the rain rate to have a negative value indicating an upward mass flux.

The surface rain rate is given by the equation

$$R_{surface} = \frac{6\pi}{10^3} \int_0^{\infty} N(D) D^3 V_{terminal}(D) dD \qquad (\text{mm hr}^{-1}). \tag{9}$$

The air density adjusted rain rate is given by the equation

$$R_{altitude}(h) = \frac{6\pi}{10^3} \int_0^\infty N(D)D^3 V_{terminal}(D)\left(\frac{\rho(h)}{\rho_0}\right)^{-0.4} dD \qquad \text{(mm hr}^{-1}) \qquad (10)$$

where h represents the height of the observations, ρ_0 is the air density at the surface, and $\rho(h)$ is the air density at the height h. Since the air density decreases with increasing altitude, the air density adjustment increases the terminal fall speed of the raindrops and $R_{altitude}$ is always greater than $R_{surface}$. The values of ρ_0 and $\rho(h)$ estimated from a seasons worth of balloon soundings launched from the Darwin Airport and the mean $\rho(h)$ profile was used in estimating the air density adjusted terminal fall speeds.

The vertical air motion adjusted rain rate is given by the equation

$$R_{air\ motion}(h) = \frac{6\pi}{10^3} \int_0^\infty N(D)D^3 \left(V_{terminal}(D)\left(\frac{\rho(h)}{\rho_0}\right)^{-0.4} - \omega(h)\right) dD \ \text{(mm hr}^{-1}) \quad (11)$$

where $\omega(h)$ is the vertical air motion at the height h estimated from the 50-MHz wind profiler. Upward air motions are defined with positive values which causes the rain rate to decrease with stronger updrafts.

6.1 ASCII Data Format

The Gamma function DSDs are saved in hourly ASCII data files. The filenames follow this naming convention: dar920_dsd_gamma_YYYY_DDD_hrHH.dat.
Where:
- dar = Darwin
- 920 = 920 MHz profiler
- dsd = raindrop size distribution
- gamma = DSD assumed to have a gamma functional form
- YYYY = year
- DDD = day of year
- hr = hour
- HH = hour of day

The DSD retrievals were processed using the vertical beam observations of the 920-MHz profiler. The profiler is configured to observe in the vertical beam direction at the start of every minute and dwell for 45 seconds. The profiler then observes in either the North or East beam for 15 seconds. Then the profiler repeats this pattern indefinitely alternating between the North and East beams. In the following data files, only the data from the vertical beam are provided. The time stamp the data file corresponds to the beginning of the dwell period.

The DSD data files are in sequential format. Each row corresponds to a particular pixel in the time-height plane. Each column corresponds to a particular variable:

Column   Description

1	year
2	day of year
3	month number
4	day of month
5	hour
6	minute
7	second
8	dayofyear.fraction of day
9	height above Mean Sea Level (MSL) (m)
10	Scale Parameter, N_w (mm^{-1} m^{-3})
11	Median Diameter, D_0 (mm)
12	Shape Parameter, μ (unitless)
13	Reflectivity (dBZ)
14	Rain rate (surface terminal fall speeds) (mm hr^{-1})
15	Rain rate (altitude terminal fall speeds) (mm hr^{-1})
16	Rain rate (altitude terminal fall speeds plus vertical air motion) (Flux of rain - could be negative) (mm hr^{-1})
17	Liquid Water Content (mm)
18	Vertical air motion, positive is upward (m s^{-1})

The ASCII numbers are expressed in exponential notation using the format: 1.2345678e+123. The sign of the exponent could be either a '+' or '-'. There are two spaces between each number, but one space is used for the '-' symbol with negative numbers.

If the power return is below the level of detectability, the DSDs are not estimated and the bad or missing data values are indicated with a value of -99.9 (-9.9000000e+001).

Data from the 25 ranges gates between 1.5 and 4 km are saved in the hourly data file. Therefore, there are 60*25= 1500 rows in each hourly data file. In all hourly data files, the data for minute 1 is missing and is set to the bad data flag.

6.2 Daily Images

For each hourly data file, three images are generated and examples are shown in Figures 7, 8, and 9. The filename for the hourly images follows this format: p_dar920_dsd_gamma_TYPE_YYYY_DDD_HH_v1.tif

Where
- p_dar920 = plot of Darwin 920 MHz profiler
- dsd = raindrop size distribution
- gamma = DSD assumed to have a gamma functional form
- TYPE = ZD0mu = 3-panel plot of Reflectivity, median raindrop diameter, and shape parameter
- TYPE = NwD0R = 3-panel plot of Scale parameter, median raindrop diameter, and surface rain rate

- TYPE = RRomega = 3-panel plot of surface rain rate, altitude rainrate, and vertical air motion
- YYYY = Year
- DDD = Day of year
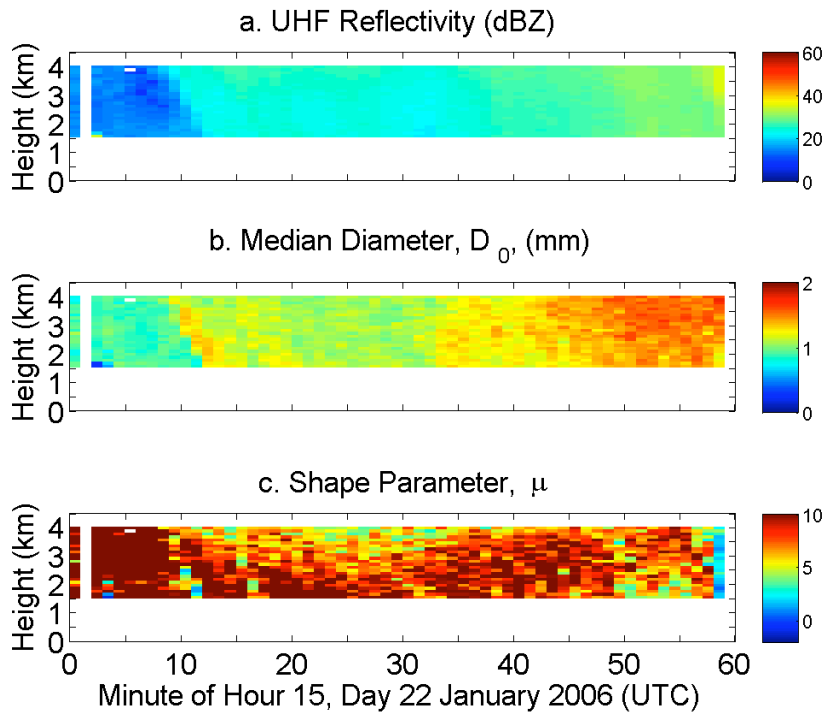- HH = hour of day
- v1.tif = version 1, tif format

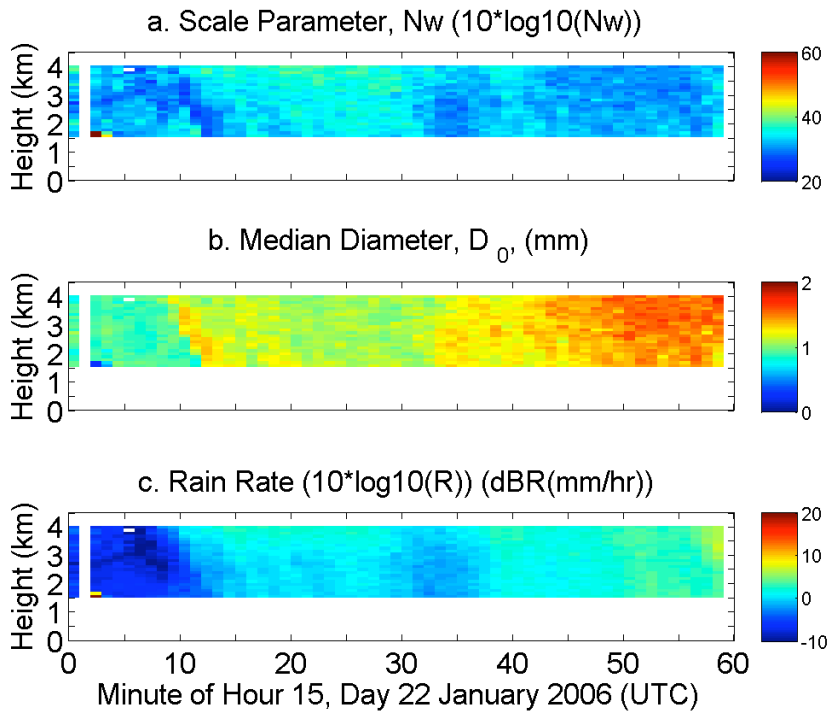Figure 7 shows the reflectivity *Z*, median raindrop diameter D_0, and the shape parameter μ.

Figure 8 shows an example of the scale parameter N_w, median raindrop diameter D_0, and surface rain rate expressed as $dBR = 10log(R)$.
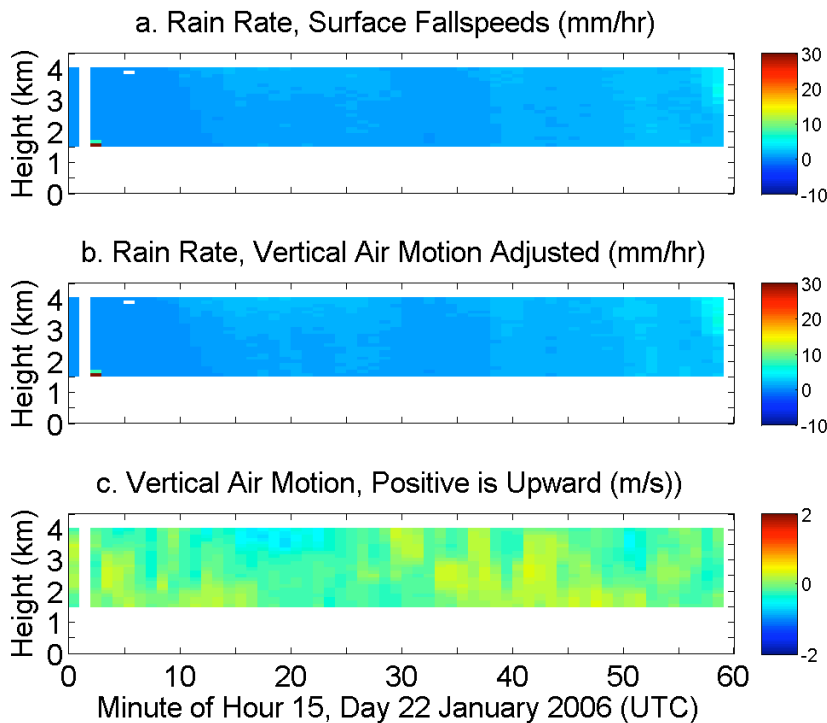

Figure 9 shows the surface rain rate $R_{surface}$, the altitude adjusted terminal fall speed rain rate $R_{altitude}$, and the vertical air motion ω .

7. Ensemble DSDs

The 50-MHz and 920-MHz profiler spectra were analyzed to estimate the raindrop size distribution (DSD) from 1.5 to 4.0 km directly above the profiler site. The retrieval method is described in detail in Williams and Gage (2009) (Ann. Geophys., 27, 555-567. 2009 www.ann-geophys.net/27/555/2009/). Basically, the retrieval method estimates the DSD at each range gate using 42 different models. These hourly data sets contain the mean, median, and the standard deviation of the precipitation parameters retrieved from the ensemble of DSD estimates. The details of estimating the 42 models and how the outlier models were removed before estimating the mean, median, and standard deviation are described in Williams and Gage (2009).

7.1 ASCII Data Format

The ensemble DSDs are saved in hourly ASCII data files. The filenames follow this naming convention: dar920_dsd_ensemble_mean_YYYY_DDD_hrHH.dat.
Where:
- dar = Darwin
- 920 = 920 MHz profiler
- dsd = raindrop size distribution
- ensemble_mean = mean, median, and STD of retrieved ensemble DSDs
- YYYY = year
- DDD = day of year
- hr = hour
- HH = hour of day

The DSD retrievals were processed using the vertical beam observations of the 920-MHz profiler. The profiler is configured to observe in the vertical beam direction at the start of every minute and dwell for 45 seconds. The profiler then observes in either the North or East beam for 15 seconds. Then the profiler repeats this pattern indefinitely alternating between the North and East beams. In the following data files, only the data from the vertical beam are provided. The time stamp the data file corresponds to the beginning of the dwell period.

The DSD data files are in sequential format. Each row corresponds to a particular pixel in the time-height plane. Each column corresponds to a particular variable:

Column	Description
1	year
2	day of year
3	month number
4	day of month
5	hour
6	minute
7	second
8	dayofyear.fraction of day
9	height above Mean Sea Level (MSL) (m)
10	mean scale parameter, N_w (mm^{-1} m^{-3})

11   mean median diameter, D_0 (mm)
12   mean reflectivity (dBZ)
13   mean rain rate (altitude fallspeeds) (mm hr^{-1})
14   mean liquid water content (mm)
15   vertical air motion, positive is upward (m s^{-1})
16   std scale parameter, N_w (mm^{-1} m^{-3})
17   std median diameter, D_0 (mm)
18   std reflectivity (dBZ)
19   std rain rate (altitude terminal fall speeds) (mm hr^{-1})
20   std liquid water content (mm)

The ASCII numbers are expressed in exponential notation using the format: 1.2345678e+123. The sign of the exponent could be either a '+' or '-'. There are two spaces between each number, but one space is used for the '-' symbol with negative numbers.

If the power return is below the level of detectability, the DSDs are not estimated and the bad or missing data values are indicated with a value of -99.9 (-9.9000000e+001). The reflectivity is averaged in standard units (mm^6 m^{-3}) and then converted to decibel units (dBZ).

Data from the 25 ranges gates between 1.5 and 4 km are saved in the hourly data file. Therefore, there are 60*25= 1500 rows in each hourly data file. In all hourly data files, the data for minute 1 is missing and is set to the bad data flag.

7.2 Daily Images

For each hourly data file, an image showing the mean ensemble liquid water content, scale parameter, and median raindrop diameter is generated as shown in Figure 10. The filename for the hourly images follows this format:
p_dar920_dsd_ensemble_mean_TYPE_YYYY_DDD_HH_v1.tif

Where
- p_dar920 = plot of Darwin 920 MHz profiler
- dsd = raindrop size distribution
- ensemble_mean = mean estimated from ensemble DSDs
- TYPE = WNwD0 = 3-panel plot of liquid water content, scale parameter, and median raindrop diameter
- YYYY = Year
- DDD = Day of year
- HH = hour of day
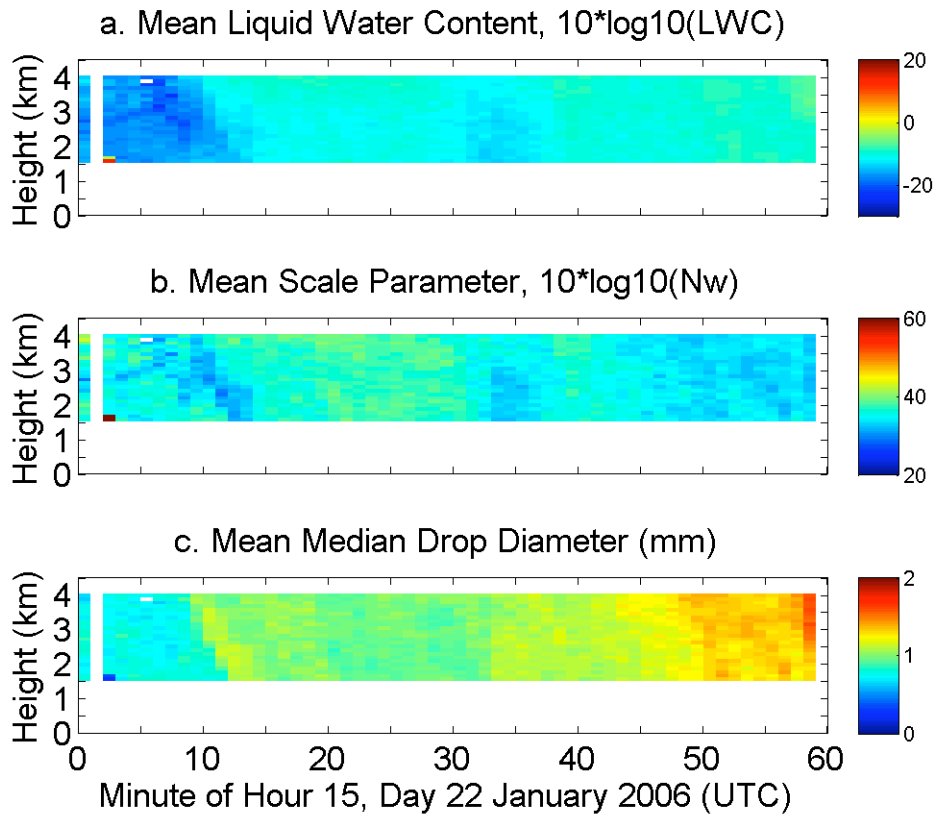- v1.tif = version 1, tif format

Figure 10. Hourly image of liquid water content (10log(LWC)), scale parameter (10log(N_w)), and median raindrop diameter D_0.