Documentation of the data collected by EPFL-LTE network of 16 optical disdrometers

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Contents

1 Introduction

1.1 Context and summary

This report documents the data collected by the EPFL-LTE network of disdrometers. The network of 16 disdrometers has been deployed over EPFL campus in Lausanne, Switzerland, for about 16 months from March 2009 to July 2010.

The next section (1.2) is presenting the disdrometer used to build this network while Section 1.3 describes the *EPFL_2009-2010* campaign during which the data have been collected. Sections 2 and 3 document the access to the data set and the file format, respectively. The two types of data files available are described in Sections 4 and 5. Finally, a summary of the available *R* [R Development Core Team, 2011] functions related to the network is presented in Section 6.

The reader is kindly invited to pay attention to the paragraph '*Citation*' in Section 7 which presents the citation policy when using this data set.

1.2 Parsivel rationale

Parsivel (manufactured by OTT Hydromet, Germany) is an optical disdrometer with a horizontal laser beam of 54 cm^2 providing DSD measurements as well as information about quantities derived from the DSD (for example the rain rate R and the radar reflectivity factor Z) and information about the type of precipitation. Figure 1 presents Parsivel disdrometer (1st generation) for illustration. When a particle

Figure 1: A picture of the 1st generation of Parsivel optical disdrometer (from Jaffrain et al. [2011]).

crosses the laser beam, the attenuation in the received voltage and the time for the particle to leave the beam are used to estimate the equivolumetric drop diameter D and the terminal fall speed v of the drop. The particle diameter is calculated from the maximum shadowed area which is related to the maximum output voltage attenuation, assuming the shape of the particle is known. Because drops larger than

1 mm are not spherical, the calculation of the equivolumetric diameter is based on different axis ratio (vertical/horizontal axis) relationships. Drops smaller than 1 mm are assumed to be spherical (axis ratio = 1) contrary to particles with a diameter larger than 5 mm for which the axis ratio is set to 0.7. For drops between 1 and 5 mm, the axis ratio varies linearly from 1 to 0.7. Parsivel retrieval rationale is described in details in Battaglia et al. [2010]. The estimated size and fall speed of the particles are stored in a 32 × 32 matrix corresponding to 32 non-equidistant classes of diameter (from 0 to 25 mm) and 32 non-equidistant classes of fall speed (from 0 to 22.4 m s^{-1}). All drops in a given class are assigned the values corresponding to the center of the size and velocity classes. Due to their low signal-to-noise ratio, the first two classes of diameter (0.062 and 0.187 mm) are always empty. Therefore, sampled diameters start at the lower bound of the third class, i.e., 0.25 mm. According to Löffler-Mang and Joss [2000] and Battaglia et al. [2010], taking into account margin fallers (i.e., particles partly detected), the effective sampling area of Parsivel can be estimated as a function of drop diameter:

$$S_{eff}(D_i) = L \times \left(W - \frac{D_i}{2} \right) \tag{1}$$

where L and W are respectively the length (180 mm) and the width (30 mm) of the laser beam and D_i is the center of the i^{th} diameter class. For calculation of drops concentration from raw spectrum (i.e., drop counts), the effective sampling area S_{eff} should be used.

1.3 The campaign

This section provides useful information concerning the data collected during the *EPFL-2009-2010* campaign. The reader is referred to Jaffrain et al. [2011] for further information on the network architecture and data acquisition.

1.3.1 Data collection

The data have been collected during a 16-month field campaign (from March 2009 to June 2010) that corresponds to the period for which all the network (16 stations) was collecting data. As the stations have not been all deployed at the same time, additional data are available before March 2009 and after June 2010. Table 1 below summarizes the operational period for each station of the network.

Table 1: Period during which each station was collecting data .

Station ID	From [UTC]	To [UTC]
10	2008-12-15 12:26:00	2010-09-28 23:59:30
11	2008-12-15 12:26:00	2010-09-28 23:59:30
12	2008-12-15 12:26:00	2010-09-28 23:59:30
13	2008-12-15 12:26:00	2010-09-23 13:28:00
20	2008-12-18 14:13:00	2010-09-17 10:49:00
21	2008-12-18 14:13:00	2010-09-17 10:49:00
22	2008-12-18 14:13:00	2010-09-17 10:49:00
23	2009-02-25 15:19:00	2010-07-09 23:47:00
30	2009-03-20 14:36:00	2010-09-26 23:59:30
31	2009-03-23 14:44:00	2010-09-26 23:59:30
32	2009-03-23 14:44:00	2010-09-26 23:59:30
33	2009-03-20 14:36:00	2010-09-26 23:59:30
40	2008-12-12 16:06:00	2010-09-29 23:59:30
41	2008-12-12 16:06:00	2010-07-07 23:59:30
42	2008-12-12 16:06:00	2010-07-07 23:59:30
43	2008-11-26 09:14:00	2010-09-17 23:59:30

1.3.2 Sampling resolution

When this campaign was initiated, the network was sampling at a 20-s temporal resolution. Due to technical limitation when the GPRS component was implemented on the network, the sampling resolution was changed to 30 s. This technical upgrade, that happens the 30^{th} of July 2009, should be taken into account (only) if the reader is working with *raw data* files (files at the original temporal resolution as provided by Parsivel, see Section 3 for further details).
Independently of the instrument considered, the temporal resolution of *raw data* files is:

- 20 s: up to the 29^{th} of July 2009, 23:59:40 [UTC].
- 30 s: from the 30^{th} of July 2009, 00:00:00 [UTC].

1.3.3 Spatial distribution

During this campaign, the 16 disdrometers have been deployed over EPFL campus in Lausanne, Switzerland. To avoid human disturbances, the instruments have been installed on the roofs of EPFL buildings, far enough from the edges in order to prevent from possible wind disturbances induced by the edges. Table 2 hereafter provides the geographic coordinates of the 16 stations of the network. Two types of coordinates are available:

- *WGS84*: Conventional geographic coordinates in the WGS84 system express in decimal degrees.
- *MN03*: Swiss coordinates with the origin in Bern (E=600000 m, N=200000 m). The coordinates are expressed in m.

The geographic coordinates have been measured with a Garmin GPS (model Dakota 20) in the WGS84 system and then converted into Swiss coordinates using the online NAVREF projection tool provided by the Swiss institute for topography (see http://www.swisstopo.admin.ch/internet/swisstopo/fr/home/apps/calc/navref.html). It should be noted that the altitude is supposed constant (400 m) for all the stations.

Table 2: Geographic coordinates of the instruments during the EPFL 2009-2010 campaign.

Station ID	WGS84 Lat [N °]	WGS84 Lon [E °]	MN03 East [m]	MN03 North [m]
10	46.520500	6.565200	532977	152507
11	46.520433	6.562833	532795	152502
12	46.521900	6.565183	532977	152663
13	46.521267	6.566767	533098	152591
20	46.519800	6.570500	533383	152425
21	46.519583	6.572317	533522	152399
22	46.521200	6.572583	533544	152579
23	46.520533	6.571100	533429	152506
30	46.518333	6.563933	532877	152267
31	46.519650	6.563900	532876	152414
32	46.518700	6.562733	532785	152309
33	46.517633	6.564583	532926	152189
40	46.521017	6.569733	533325	152561
41	46.519500	6.567883	533181	152394
42	46.520600	6.567850	533180	152516
43	46.521400	6.567867	533182	152605

1.4 List of precipitation events

A list of precipitation events that have been collected during this 16-month campaign is provided with the data. However, it should be noted that this list of precipitation events (.ods or .xls) has been generated automatically from the disdrometer data in order to help the user to select and identify rainfall events. It is indicative and based on the following conditions:

- The minimum duration of a precipitation event is 15 min.
- The minimum rain amount collected during the event should be larger or equal to 1 mm.
- Two consecutive precipitation events should be separated by a dry period of at least 15 min.
- The starting and ending time provided in the list is not the first and last wet time step. The provided timing take into account a surrounding period of 10 min (start=1^{st} time step wet - 10 min, end=last time step wet + 10 min) in order to be sure to catch the whole precipitation event.

- Station(s) with more than 20% of missing measurements are considered as not providing data for the considered event.

The file containing this list is named '*Precip_Events_Network_2009-2010*'. The columns present the characteristics and statistics associated with each precipitation event (1 event per line), and are organized as follow:

1. *Evt #*: identification number of the event.
2. *Stations*: a cross indicates that the associated station has collected data (less than 20% of missing measurements) during the considered event. On the other hand, a grey background indicates more than 20% of missing measurements.
3. *Peak mean R*: peak rain rate [mm h^{-1}] averaged over the network (available stations).
4. *Mean amount*: averaged rain amount collected over the network.
5. *Max R*: maximum peak rain rate recorded by a single station.
6. *Sta Max R*: station ID that has recorded the maximum peak rain rate.
7. *Max Ra*: maximum rain amount recorded by a single station during the event.
8. *Sta Max Ra*: station ID that has recorded the maximum rain amount.
9. *Predominant precip type*: predominant type of precipitation recorded during the event. The associated % gives the percentage of measurements that were of this type of precipitation.

2 Data file access

The data are accessible through a NASA server at `ftp://gpm.nsstc.nasa.gov/gpm_validation/related_projects/epfl/`:

- The directory “Library" contains the R routines detailed in Section 6.
- The directory “Data" contains the DSD date described in Section 4 and 5.
- The directory “Doc" contains the documentation associated with the data set.

3 Data file architecture

3.1 Types of file

Two types of file are available for this campaign:

- *Raw data*: these are the original data files as provided by Parsivel according to our set up. The sampling resolution depends of the period of interest (20 or 30 s, see Section 1.3.2 for further details). This type of file is presented in details in Section 4.

- *Filtered volumic DSD*: it corresponds to data files created from the original ones (raw data) providing the volumic DSD [m^{-3} mm^{-1}] with a preliminary filtering process. The sampling resolution is 60 s. Further information is provided in Section 5.

3.2 File compression

In order to share these data and to ease file transfer, all the data files have been compressed using **GZip**. The associated file extension is '*.gz*'. More info is available at http://www.gzip.org/. It is a multi-platform file compressor. Nevertheless, additional file compressors manage '*.gz*' format (such as WinRar for instance).

3.3 File nomenclature

Independently of the type of file, the data set consists of daily data files with measurements collected from 00:00:00 [UTC] of the day of interest to the last time step before midnight of the next day (for instance, 23:59:30 at a 30-s temporal resolution).

The files are organized according to the station identification numbers (2 digits number) and the collecting date in the format Year (4 digits), month (2 digits) and day (2 digits). File names are starting with the prefix ("DSDraw-") for raw DSD files and the prefix ("DSDfilt-") for filtered DSD files. For example, the file '*DSDraw-10_ascii_20110115.dat*' corresponds to the *raw data* collected by station *10* for the 15^{th} (*15*) of January (*01*) 2011 (*2011*) from 00:00:00 [UTC] to the last time step before midnight of the next day (for instance, 23:59:30 at a 30-s temporal resolution).

3.4 File format

After the decompression process, the file has the extension '*.dat*' for raw data files and '*.txt*' for volumic DSD files. Both types of file correspond to data in *ascii* format. Each measurement corresponds to a new line in which each measured parameter is provided between quotation marks ("). The different parameters are separated by commas. No header is present for raw data files (the first line corresponds to the first measurement) contrary to *DSDfilt-* files.

3.5 Summary

Table 3: Caracteristics of each type of file.

	Raw data	Filtered DSD
Compressed (*.gz*)	yes	yes
File name prefix	"DSDraw-"	"DSDfilt-"
File name base	"ID_ascii_YYYYMMDD"	"ID_ascii_YYYYMMDD"
File extension	.dat	.txt
Header	No	Yes
Temporal resolution	20 or 30 s	60 s

Table 3 legend:

ID: station identification number (2 digits)

YYYY: Year at a 4 digits format

MM: Month at a 2 digits format

DD: Day at a 2 digits format

4 Raw data

This section presents all the parameters available in the raw data (i.e., **directly provided by the instrument** according to our setup) collected by EPFL-LTE Parsivels. The files are provided at the original temporal resolution (20 or 30 s). All the different parameters are summarized in the table below.

Table 4: List of parameters available in EPFL-LTE Parsivel data.

Position	Parameter	Format	Units
01	Date and Time	YYYY-MM-DD hh:mm:ss	UTC
02	Record number	-	-
03	Logger temperature	-	°C
04	Logger voltage	-	V
05	Parsivel rain rate	-	mm h^{-1}
06	Parsivel rain amount	-	mm
07	Precipitation code 4680	-	-
08	Precipitation code 4677	-	-
09	Parsivel radar reflectivity	-	dBZ
10	Visibility in the precipitation	-	m
11	Laser amplitude	-	-
12	Number of particles detected	-	-
13	Parsivel temperature	-	°C
14	Parsivel heating current	-	A
15	Parsivel voltage	-	V
16	Parsivel status	-	-
17	Absolute amount	-	?
18	Transmit time	-	-
19	Field N	Vector of 32 values	m^{-3} mm^{-1}
20	Field v	Vector of 32 values	?
21	Raw data	Vector of 1024 values	-
22	Communication error	-	-

4.1 Parsivel precipitation codes (parameters # 07-08)

Parsivel classifies precipitation according to 8 types. The classification is based on a velocity-diameter relationships (see Löffler-Mang and Joss [2000] for details). Appendix A presents the list of the different precipitation codes.

4.2 Parsivel status (parameter # 16)

Parsivel disdrometer provides at each measurements a code (parameter # 16) that evaluate the quality of the measurement according to the status of the optics. Figure 2 presents the different status of the sensor as provided by the manufacturer.

> Depending on the time of year and location, air pollution can lead to contamination of the laser's protective glass. This can result in a drop in the sensor dynamics. The last value (Sensor status) of the OTT telegram provides a reference concerning the current state of the optics, wherein the following error codes are reported:
>
> 0 = Everything OK
> 1 = Laser protective glass is dirty, but measurements are still possible
> 2 = Laser protective glass is dirty, partially covered. No further usable measurements are possible
> 3 = Laser damaged

Figure 2: Parsivel status as provided by the manufacturer (p. 36 of the manual).

4.3 Field N (parameter # 19)

Parsivel disdrometer is providing a large number of parameters related to the raindrop size distribution (denoted hereafter DSD). One of these corresponding to line 90 in the data telegram, is called *Field N*. It corresponds to the logarithm (base 10) of the concentration of drops according to the 32 Parsivel diameter classes. Consequently, the associated units are [m^{-3} mm^{-1}]. This logarithm conversion was implemented by the manufacturer in order to reduce the size of data files generated by Parsivel (drop concentration values can be very high). The following conversion is required to back-transformed Parsivel outputs into a concentration of raindrops:

$$N_{FieldN}(D) = 10^{FieldN_{Parsivel}} \tag{2}$$

The default value provided by Parsivel when no drops are recorded in the diameter class of interest is *-9.999* corresponding to a concentration of drops near zero ($10^{-9.999}$).

4.4 Field V (parameter # 20)

Parsivel disdrometer is as well providing a parameter called *Field V* corresponding to the line 91 of the data telegram. It is still not clear what this parameter is. It is supposed to be a weighted terminal fall speed according to each drop diameter classes.

4.5 Raw spectrum (parameter # 21)

A clear advantage of Parsivel disdrometer is the possible access to the DSD raw data in the line 93 of the telegram. It corresponds to the 32×32 drop counts (=1024 values) and is consequently unit-less. It has to be noticed that the 1024 values are ordered according to the diameter classes. In other words, the first 32 values correspond to the 32 drop diameters and the first fall velocity. Similarly, the 33rd value corresponds to the the number of drops with a diameter $D = D_1$ and a fall speed $V = V_2$.

The 32 diameter and velocity classes are presented in Appendix B and C respectively.

5 "DSDfilt-" files

5.1 File format

To distinguish this type of files from the *raw data* ones, the associated file names are starting with a prefix (*DSDfilt-*). The remaining part of the file name is similar to the raw data files and consists of (in this order): the 2-digit identification number of the station, "_ascii_", the date of the data file with the format *YYYYMMDD*, and the extension "*.txt*" (uncompressed data, see Section 3).

Contrary to the raw data files, these files have a 1-line header that must be taken into account when reading the data. For consistency, the temporal resolution of these files is 60-s (trade-off between 20 s and 30-s temporal resolution) for the whole campaign.

5.2 Precipitation indicator

As shown in Section 4.1, Parsivel provides a precipitation code divided into 8 types. While this classification is not convenient when re-sampling data to larger temporal resolutions (the sum or mean of precipitation codes does not have any physical sense), it is important to keep such information as solid and liquid precipitation have been collected by the network during this campaign. Consequently, a parameter denoted '*precipitation indicator*' summarizes this information in the processed data files.

The precipitation indicator (denoted *pi* hereafter) can have the following values:

- *NA*: no measurement available (no data from this station).
- *-1*: no rain recorded (dry period).
- *0*: all the 20-s or 30-s time steps used to estimate this 60-s measurement are associated with **liquid rain**.
- *1*: all the 20-s or 30-s time steps used to estimate this measurement have recorded solid precipitation.

- $0<pi<1$: percentage of solid precipitation in this measurement (for instance, ri=0.33 means that 33% of the original time steps are associated with solid precipitation).

- *-2*: a few drops have been collected (corresponding to drizzle) but Parsivel has filtered them. In other words, the instrument has calculated a zero rain rate value with a few drops in the raw DSD spectrum (parameter #21). As Parsivel is associating the original raw data measurement to a precipitation type equal to zero (no rain), no information on precipitation type is available.

5.3 Filtered volumic DSD

In the DSD raw data (parameter #21), Parsivel provides all the detected particles. To identify and remove suspicious measurements (due to splashing, multiple drops at a time, margin fallers, insects, spiders, ...), a filter based on drop velocity-diameter relationship, similar to the one used by Kruger and Krajewski [2002] and Thurai and Bringi [2005], is applied to the raw Parsivel measurements (32×32 drop counts). The drop velocity model is taken from Beard [1977].

Using a data set collected during a 15-month experiment involving collocated Parsivels and tipping-bucket rain gauges [see Jaffrain and Berne, 2011], the tolerance around this model is set to 60% when comparing rain amount data from the two types of instruments. Finally, only drops satisfying the equation:

$$| v(D)_{meas} - v(D)_{Beard} | \leq 0.6 \; v(D)_{Beard} \tag{3}$$

are considered, where $v(D)_{meas}$ is the velocity mesured by Parsivel and $v(D)_{Beard}$ is the velocity for a drop of diameter D according to Beard's model. Such filter removes about 25% of the total number of particles detected (but only a few % of the total rain amount).

Using this filtered 32×32 drop counts, the volume drop concentration is calculated (expressed in [m^{-3} mm^{-1}]). It has to be noted that the effective sampling area (see Eq.1) is used to calculate the volume drop concentration.

6 Library of R functions

This section describes the different functions provided in the R library (file 'Library_Rcran-Switzerland_EPFL.R'). The functions are listed alphabetically hereafter.

get.network_coordinates

The function '*get.network_coordinates*' provides the coordinates (WGS84 and MN03, see Section 1.3.3) of each station of the network. The parameters available as input are:

- *id_station*: a single value or a vector with the ID of the station(s) of interest (e.g., 10, 11 12, ...).

- *all*: optional logical argument (default=FALSE). If set up to 'TRUE', the function return the coordinates of all the 16 stations of the network.

The output is a matrix with one line per station and 6 columns that give:

1. The station ID.
2. WGS84 Latitude [N °].
3. WGS84 Longitude [E °].
4. Altitude [m].
5. MN03 East Swiss coordinates [m].
6. MN03 North Swiss coordinates [m].

get.network_station_distance

This function returns the distance [m] between two stations of the network. Two parameters need to be provided as input: *id_station1* and *id_station2* that give the ID (2 digits) of the stations of interest.

Parsivel_classes

This function groups the useful information concerning Parsivel DSD measurements. These values have been implemented according to OTT-Parsivel manual (p. 43 and 44).

No input is required for this function. The output is a list with different objects:

- *class_size*: a vector of 32 values corresponding to the center of Parsivel diameter classes [mm].
- *class_speed*: a vector of 32 values corresponding to the center of Parsivel velocity classes [m s^{-1}].
- *class_size_spread*: a vector of 32 values corresponding to the spread of Parsivel diameter classes [mm].

uncertainty_Parsiv

The '*uncertainty_Parsiv*' function provides the sampling uncertainty values associated with Parsivel measurements. The reader is referred to Jaffrain and Berne [2011] for more-in-depth information on the method. It has to be noticed that this function does not calculated uncertainty values but rather provide the uncertainty values according to the magnitude of the quantity of interest and the temporal sampling resolution.

The different inputs to specify are:

- *vect*: a vector of values recorded by Parsivel for which the user want to have the associated uncertainty values. **The values provided should have the same units than the parameter specified in the '*var_type*' parameter**.

- *var_type*: a character vector with the name of the variable of interest. The different variables available as well as there respective acronyms and units are:

  - "Nt": total concentration of drops [m^{-3}]
  - "D0": median-volume drop diameter [mm]
  - "Dmw": mass-weighted drop diameter [mm]
  - "R": rain rate [mm h^{-1}]
  - "Z": radar reflectivity [dBZ]
  - "Zdr": differential reflectivity [dBZ]
  - "ah": specific attenuation at horizontal polarization[dB km^{-1}]
  - "kdp": specific differential phase [^{o} km^{-1}]

- *dt*: temporal resolution of the vector values [s]. The temporal resolution should be between 20 and 3600 s (i.e., 1h). **This function is automatically interpolating uncertainty values using least squared method if the requested temporal resolution is different from the one presented in Jaffrain and Berne [2011]**.

- *freq*: optional (default=9.4), radar frequency [GHz] to consider for radar quantities (i.e., Z, Zdr, ah and kdp). The available values are: 9.4, 5.6 and 2.8 for X-, C- and S-band respectively.

- *fill.na*: optional (default=FALSE), logical parameter specifying if NA uncertainty values (usually for large magnitude classes) should be replaced by the calculated uncertainty value of the closest class. This is only available for Nt, R, Zh and kdp because they exhibit a similar pattern with the highest uncertainty values observed for high temporal resolutions and small magnitude classes. As for these parameters the uncertainty is decreasing for large magnitudes and longer time steps, the NA values associated with larger classes of magnitude can be set to the last available value of uncertainty (i.e., value associated with the closest class of magnitude at the same temporal resolution).

The output is a matrix with two columns that respectively contain:

1. vector of relative uncertainty values [between 0 and 1, with 1 being 100% of uncertainty]

2. vector of absolute uncertainty values [units corresponding to the parameter of interest]. This vector is calculated by multiplying the input vector to the vector of relative uncertainty values.

7 Additional information

Instrument information

Please see Löffler-Mang and Joss [2000] and Battaglia et al. [2010] for further details on Parsivel rationale.

Additional information on EPFL-LTE network of disdrometer

Please see Jaffrain et al. [2011] for technical information concerning EPFL-LTE network of disdros and the associated 16-month campaign.

Sampling uncertainty associated with Parsivel measurements

Please see Jaffrain and Berne [2011].

Citation

Please refer to Jaffrain et al. [2011] if you use the data and to Jaffrain and Berne [2011] if you use the uncertainty values.

References

Battaglia, A., E. Rustemeier, A. Tokay, U. Blahak, , and C. Simmer, 2010: PARSIVEL snow observations: a critical assessment. *J. Atmos. Oceanic Technol.*, **27 (2)**, 333–344, doi:10.1175/2009JTECHA1332.1.

Beard, K. V., 1977: Terminal velocity adjustment for cloud and precipitation drops aloft. *J. Atmos. Sci.*, **34 (8)**, 1293–1298.

Jaffrain, J. and A. Berne, 2011: Experimental quantification of the sampling uncertainty associated with measurements from Parsivel disdrometers. *J. Hydrometeor.*, **12 (3)**, doi:10.1175/2010JHM1244.1.

Jaffrain, J., A. Studzinski, and A. Berne, 2011: A network of disdrometers to quantify the small-scale variability of the raindrop size distribution. *Water Resour. Res.*, **47**, W00H06, doi:10.1029/2010WR009872.

Kruger, A. and W. F. Krajewski, 2002: Two-dimensional video disdrometer: a description. *J. Atmos. Oceanic Technol.*, **19 (5)**, 602–617.

Löffler-Mang, M. and J. Joss, 2000: An optical disdrometer for measuring size and velocity of hydrometeors. *J. Atmos. Oceanic Technol.*, **17 (2)**, 130–139.

R Development Core Team, 2011: *R: A Language and Environment for Statistical Computing.* Vienna, Austria, R Foundation for Statistical Computing, URL `http://www.R-project.org/`, ISBN 3-900051-07-0.

Thurai, M. and V. N. Bringi, 2005: Drop axis ratios from a 2D video disdrometer. *J. Atmos. Oceanic Technol.*, **22 (7)**, 966–978, doi:10.1175/JTECH1767.1.

A Parsivel precipitation codes (p. 45 of the manual)

C.1 Precipitation code according to SYNOP

The definitions of the precipitation codes below are listed according to the following tables:

- SYNOP $w_a w_a$ Table 4680
- SYNOP ww Table 4677

Drizzle

Intensity	Rain rate [mm/h]	Tab. 4680	Tab. 4677
light	≤0.2	51	51
moderate	0.2 …0.5	52	53
strong	≥ 0.5	53	55

Drizzle with rain

Intensity	Rain rate [mm/h]	Tab. 4680	Tab. 4677
light	≤0.2	57	58
moderate	0.2 …0.5	58	59
strong	≥ 0.5	58	59

Rain

Intensity	Rain rate [mm/h]	Tab. 4680	Tab. 4677
light	≤0.2	61	61
moderate	0.5 …4.0	62	63
strong	≥ 4.0	63	65

Rain, drizzle with snow

Intensity	Rain rate [mm/h]	Tab. 4680	Tab. 4677
light	≤0.5	67	68
moderate	> 0.5	68	69

Snow

Intensity	Rain rate [mm/h]	Tab. 4680	Tab. 4677
light	≤0.5	71	71
moderate	0.5 …4.0	72	73
strong	≥ 4.0	73	75

Snow grains

Intensity	Rain rate [mm/h]	Tab. 4680	Tab. 4677
light	≤0.5	77	77
moderate	0.5 …4.0	77	77
strong	≥ 4.0	77	77

Freezing rain

Intensity	Rain rate [mm/h]	Tab. 4680	Tab. 4677
light	≤0.4	87	87
moderate	> 0.4	88	88

Hail

Intensity	Rain rate [mm/h]	Tab. 4680	Tab. 4677
light	≤ 7.5	89	89
moderate	≥ 7.5	89	90

B Parsivel drop diameter classes (p. 43 of the manual)

Classification according to volume-equivalent diameter

Class Number	Class Average in mm	Class Spread in mm
1	0.062	0.125
2	0.187	0.125
3	0.312	0.125
4	0.437	0.125
5	0.562	0.125
6	0.687	0.125
7	0.812	0.125
8	0.937	0.125
9	1.062	0.125
10	1.187	0.125
11	1.375	0.250
12	1.625	0.250
13	1.875	0.250
14	2.125	0.250
15	2.375	0.250
16	2.750	0.500
17	3.250	0.500
18	3.750	0.500
19	4.250	0.500
20	4.750	0.500
21	5.500	1.000
22	6.500	1.000
23	7.500	1.000
24	8.500	1.000
25	9.500	1.000
26	11.000	2.000
27	13.000	2.000
28	15.000	2.000
29	17.000	2.000
30	19.000	2.000
31	21.500	3.000
32	24.500	3.000

C Parsivel drop velocity classes (p. 44 of the manual)

Classification according to speed

Class Number	Class average in m/s	Class spread in m/s
1	0.050	0.100
2	0.150	0.100
3	0.250	0.100
4	0.350	0.100
5	0.450	0.100
6	0.550	0.100
7	0.650	0.100
8	0.750	0.100
9	0.850	0.100
10	0.950	0.100
11	1.100	0.200
12	1.300	0.200
13	1.500	0.200
14	1.700	0.200
15	1.900	0.200
16	2.200	0.400
17	2.600	0.400
18	3.000	0.400
19	3.400	0.400
20	3.800	0.400
21	4.400	0.800
22	5.200	0.800
23	6.000	0.800
24	6.800	0.800
25	7.600	0.800
26	8.800	1.600
27	10.400	1.600
28	12.000	1.600
29	13.600	1.600
30	15.200	1.600
31	17.600	3.200
32	20.800	3.200