# Techniques for Validating DPR Level 2 Products in Italy

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# OUTLINE

Using a different retrieval method (SNM) to validate DPR rain products

Micro Rain Radar: assessing the influence vertical wind

Disdrometer: using disdrometer to evaluate DPR product in Italy

## Using a different retrieval method (SNM) to validate DPR rain products

1. A self-consistent numerical method ( **S N M** ) based on numerically solving the dual-frequency inversion equations without look-up tables was proposed [1].

2. It is evaluated using D3R measurements of IFloodS experiment. Then it is applied to DPR data and compared to DPR (version 4, September 1, 2014 - February 28, 2017).

3. SNM retrievals are compared with corresponding GPM-DPR products.


[1] E. Gorgucci and L. Baldini, “A Self-Consistent Numerical Method for microphysical retrieval in rain using GPM dual-wavelength radar,” J. Atmos. Oceanic Technol., 33, 2205–2223,. 2016.

[2] E. Gorgucci and L. Baldini, "Performance evaluations of rain microphysical retrieval using GPM dual-wavelength radar by way of comparison with the Self-Consistent Numerical Method," in IEEE Transactions on Geoscience and Remote Sensing, 2018. doi: 10.1109/TGRS.2018.2824399

# Validation of DPR rain retrievals using the SNM method

## Dual frequency retrieval

$$\xi_{u,a} = C_{\xi_{u,a}} \int_0^\infty \sigma_B(\lambda_{u,a}, D) N(D)\, dD$$

effective reflectivity factors ($mm^6 m^{-3}$) at $\lambda_a$ , $\lambda_u$

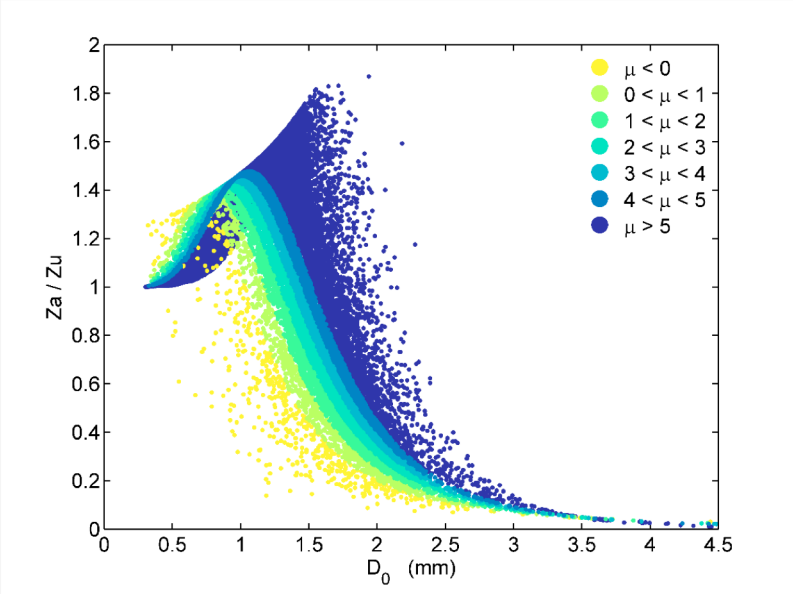
$$k_{u,a} = C_{k_{u,a}} \int_0^\infty \sigma_E(\lambda_{u,a}, D) N(D)\, dD$$

are specific attenuations ($dB\ km^{-1}$) at $\lambda_a$ , $\lambda_u$

Assuming a gamma DSD with fixed μ, for each range bin $r_j$

$$DFR(r_j) = \frac{\xi_u(r_j)}{\xi_a(r_j)} = \frac{N_0 B_u(D_0, \mu)}{N_0 B_a(D_0, \mu)} = \frac{B_u\left(D_0(r_j)\right)}{B_a\left(D_0(r_j)\right)} = f\left(D_0(r_j)\right)$$

$$D_0(r_j) = f^{-1}[DFR(r_j)]$$




*DFR versus $D_0$ Gamma DSD fitting with variable μ to IFloodS 2DVD dataset*

Solution for $D_0(r_j)$ is obtained using lookup table DSD with fixed μ and $_N0$ from expression of $\xi_u$ or $\xi_a$

# SMN validation using vertical profiles from D3R measurements

Reference vertical profiles are derived from IFloods D3R RHIs measurements

1. Individual rays were corrected from attenuation using the differential phase shift at Ku band.
2. SNM is applied to Ka and Ku reflectivity profiles to obtain DSD profiles ($Z_a$, $Z_u$) from which to derive specific attenuation profiles and corresponding measured profiles of reflectivities ($Zm_a$, $Zm_u$)
3. Profiles are resampled at DPR vertical resolution
4. The constrained DSD model Williams et al. JAMC 2014 is used

- Independent Gaussian errors with mean~0 and $\sigma$ ~1 dB are superimposed onto $Z_u$ and $Z_a$ profiles.
- The $D_0$ dual-value solution is neglected (the larger value is assumed).

| PERFORMANCE OF SNM RETRIEVALS ( $\mu$=3, NO BIASES IN PIA) | | | | | | |
|---|---|---|---|---|---|---|
| | ***WITHOUT*** MEASUREMENT ERRORS | | | ***WITH*** MEASUREMENT ERRORS | | |
| | **NSE** | **NB** | $\rho$ | **NSE** | **NB** | $\rho$ |
| $Z_u$ | 0.001 | 0.0 | 1.0 | 0.001 | 0.0 | 1.0 |
| $Z_a$ | 0.001 | -0.001 | 1.0 | 0.006 | -0.002 | 0.99 |
| $\log_{10}N_w$ | 0.014 | -0.008 | 0.99 | 0.150 | -0.007 | 0.88 |
| $D_m$ | 0.027 | 0.005 | 0.99 | 0.109 | 0.013 | 0.86 |
| $k_u$ | 0.026 | -0.002 | 0.99 | 0.377 | 0.007 | 0.97 |
| $k_a$ | 0.066 | 0.004 | 0.99 | 0.449 | 0.026 | 0.93 |
| R | 0.090 | 0.007 | 0.99 | 0.599 | 0.039 | 0.92 |

# DPR products compared to SNM outputs

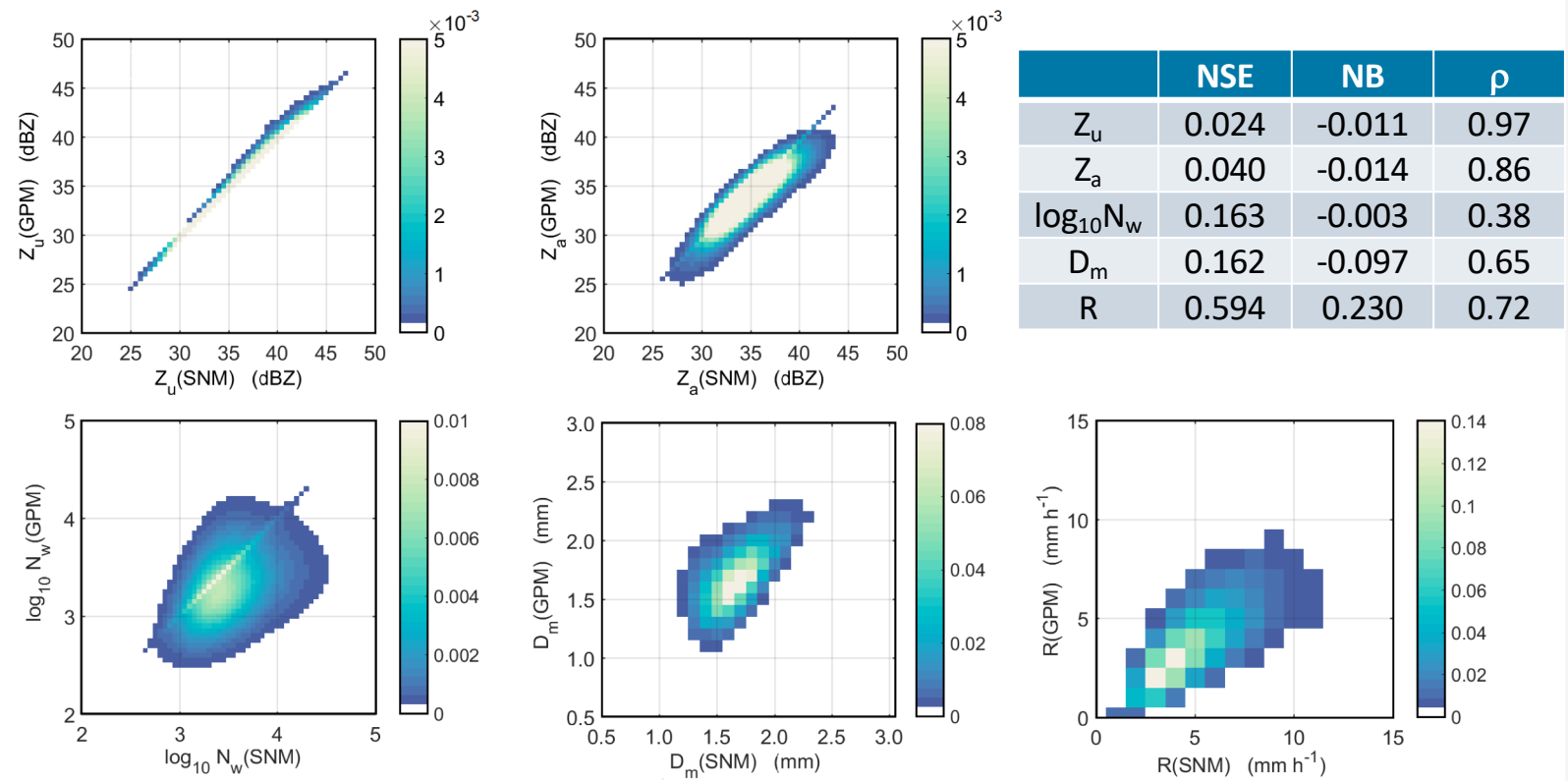
Profiles of **version 4 DPR MS** collected from September 1, 2014, to February 28, 2017 were selected if:

1. Average precipitation rate from 2 up to 4 km height >0 ;
2. Precipitation recorded in the range bin nearest to the ground;
3. Bright Band detected at Ku-band;
4. All the range bins between the BB bottom and the clutter-free bottom filled with rain and consists of more than 10 range bins;
5. Ka-band reflectivity greater than 18 dBZ.
6. Collected over ocean

The selected profile concern *stratiform precipitation* conditions to reduce the effects related to the multiple scattering and non-uniform beam filling.

SNM was run using PIA at Ka and Ku available from GPM product

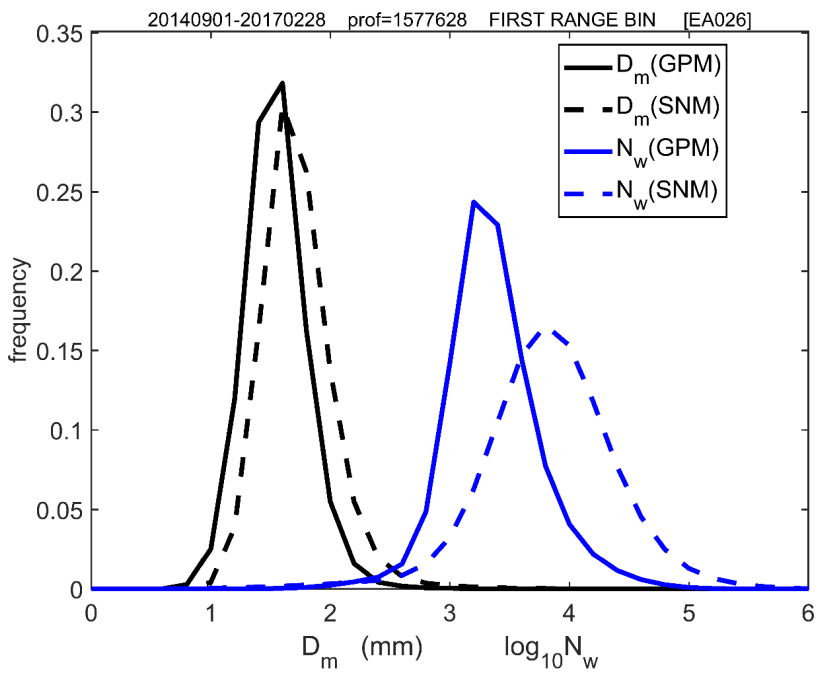
# DPR products compared to SNM outputs

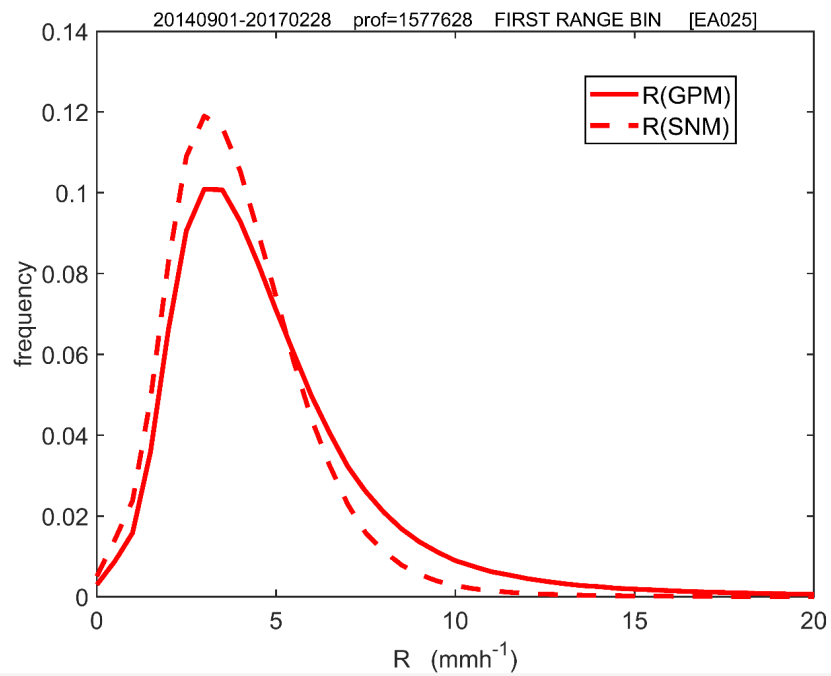



| | NSE | NB | ρ |
|---|---|---|---|
| $Z_u$ | 0.024 | -0.011 | 0.97 |
| $Z_a$ | 0.040 | -0.014 | 0.86 |
| $\log_{10}N_w$ | 0.163 | -0.003 | 0.38 |
| $D_m$ | 0.162 | -0.097 | 0.65 |
| R | 0.594 | 0.230 | 0.72 |

# DPR products compared to SNM outputs (near to ground)

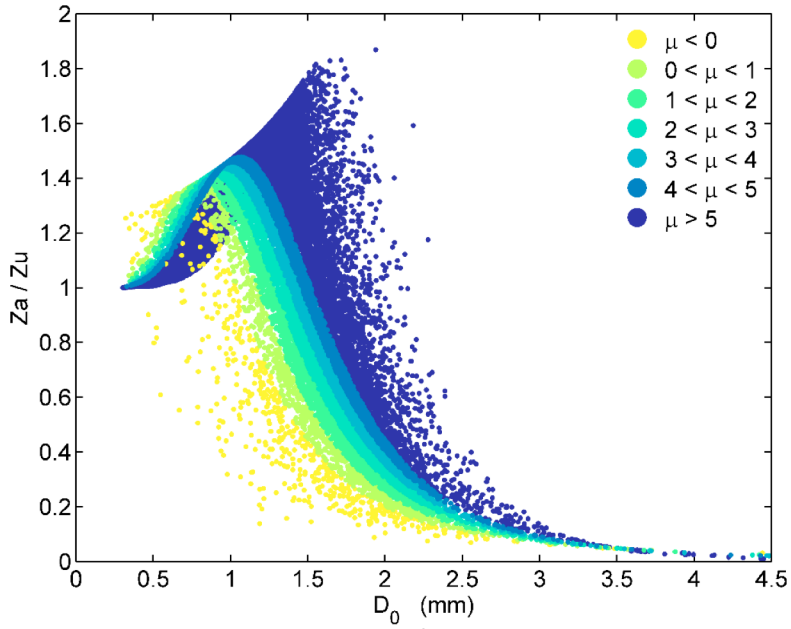
Histograms of the retrievals shows that for GPM method (variable μ), an overestimated dB$N_w$ does not correspond to an underestimated $D_m$ .



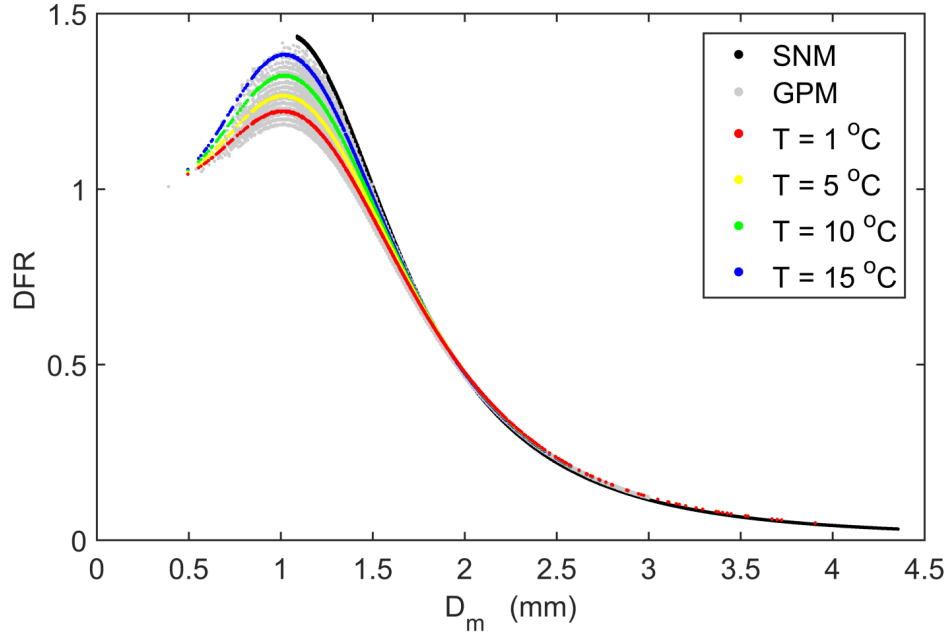



# DPR products compared to SNM outputs

Using same PIAa and PIAu, differences in estimates in the bin closest to the ground are due to the different environmental temperature chosen (T variable or T=20°) and signal fluctuation.




*DFR versus $D_0$ Gamma DSD fitting with variable $\mu$ to IFloodS 2DVD dataset*

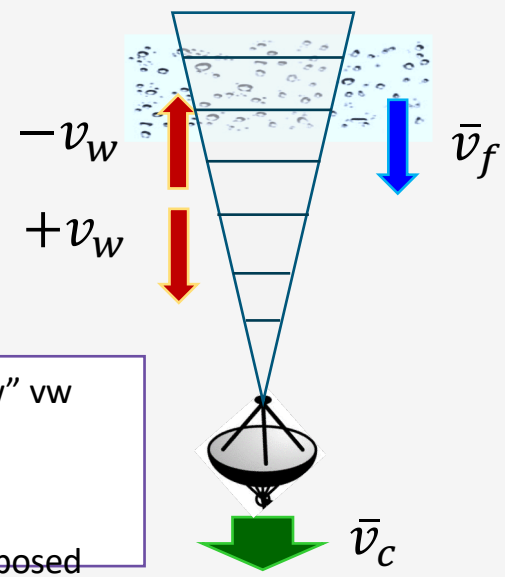



*DFR vs. $D_m$ of GPM V. 4 and SNM. In colors: DFR vs. $D_m$ simulated with different T and $\mu$=3.*

# Estimating vertical wind using MRR (Poster 233)

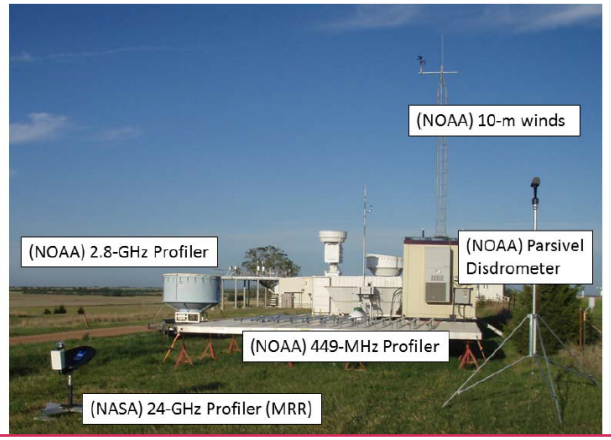
1. Metek Micro Rain Radar is a popular 25 GHz FMCW profiler for DSD retrieval
2. Retrieval of DSD from Doppler spectra collected at vertical incidence assumes a diameter-terminal velocity relation, usually derived in still-air conditions
3. The fall velocity of particles ($v_c$) measured by Doppler radars is modelled with a sum of two contributions:
   a. terminal velocity of particles ($v_f$)
   b. wind velocity ($v_w$)
3. In general $v_w$ results in a bias in DSD retrievals

$$\bar{v}_c(h) = \bar{v}_f(h) \mp v_w(h)$$

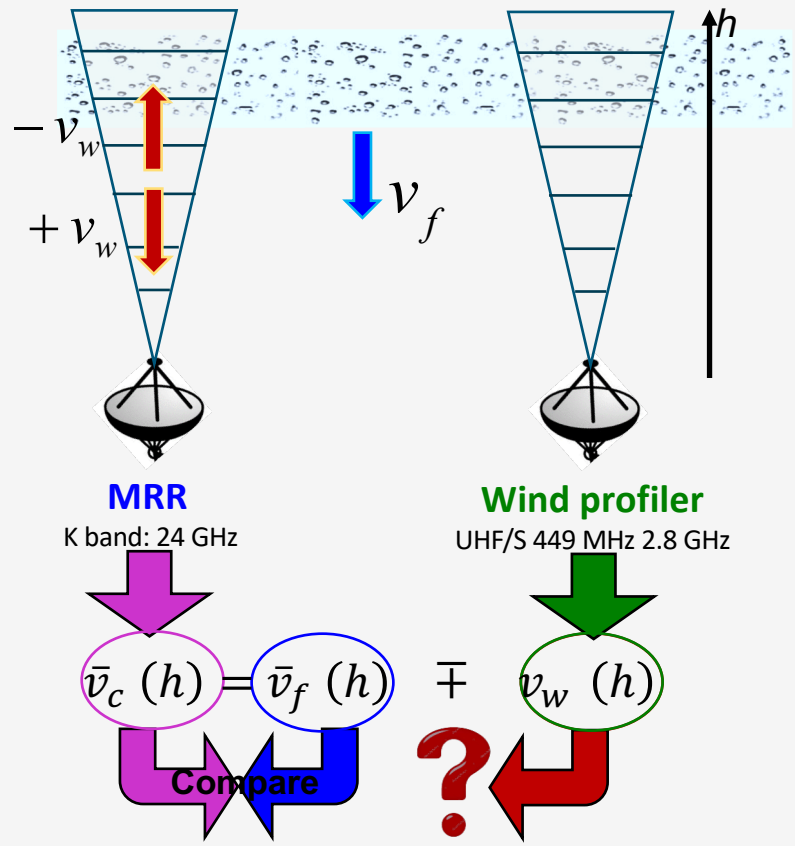



> Many campaigns and fixed installation use MRR : DSD estimates are unbiased for “low” vw (Peters et al. 2015), but often are discarded in convection
> An estimate of wind velocity should be provided in these cases
> A method to constrain MRR characteristic velocity to disdrometer estimation was proposed (Adirosi et al. 2014) but limiting to the lowest bin

# Measurements from MC3E IOP 2011




- Evaluate the impact of environmental wind velocity on retrievals of rain drop size distribution from MRR using UHF/S band wind profiler to compensate for vertical wind velocity effect

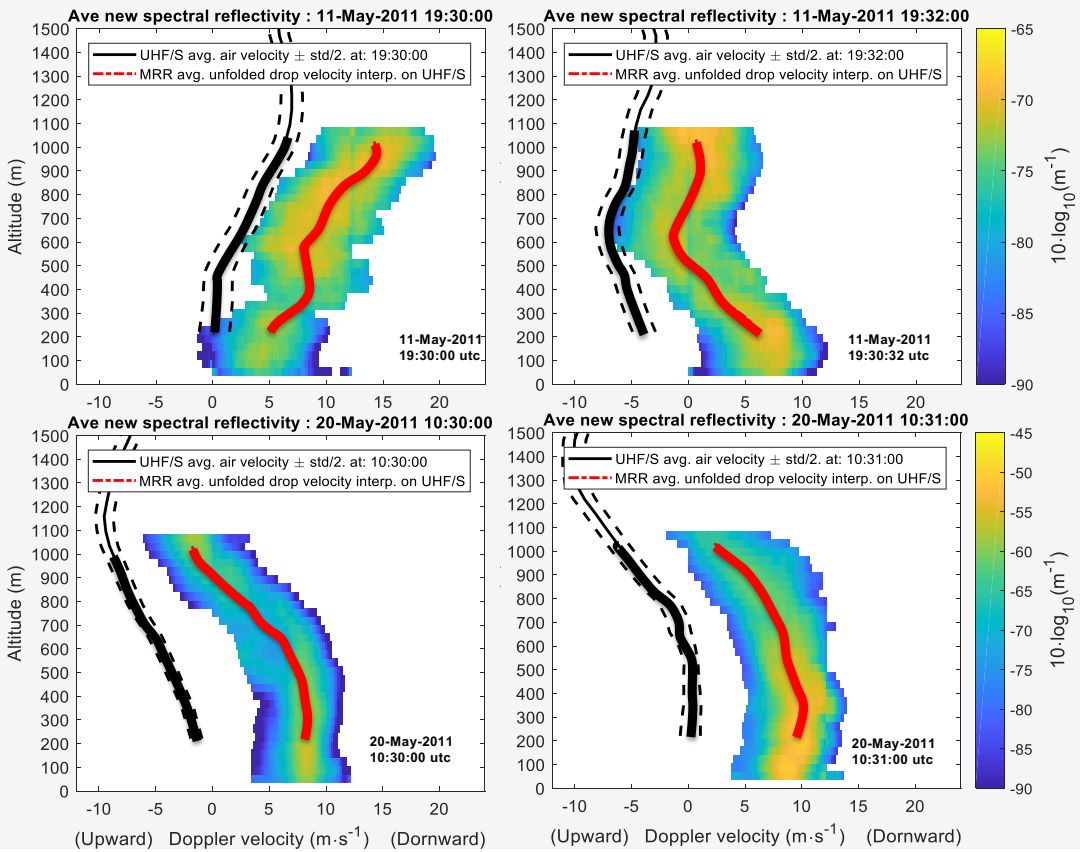




Williams, C.R., 2016: Reflectivity and Liquid Water Content Vertical Decomposition Diagrams to Diagnose Vertical Evolution of Raindrop Size Distributions. *J. Atmos. Oceanic Technol.*, **33**, 579–595,

Williams, C.R., 2012: Vertical Air Motion Retrieved from Dual-Frequency Profiler Observations. *J. Atmos. Oceanic Technol.*, **29**, 1471–1480,

# Comparison of MRR and wind profiler




**MRR average velocity**

– 1 min characteristic velocity

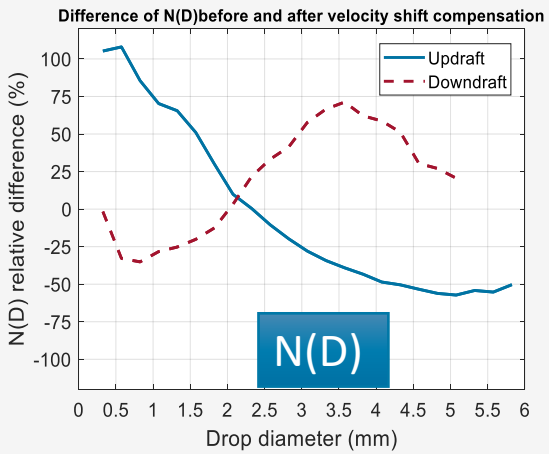
**UHF/S vertical wind velocity**

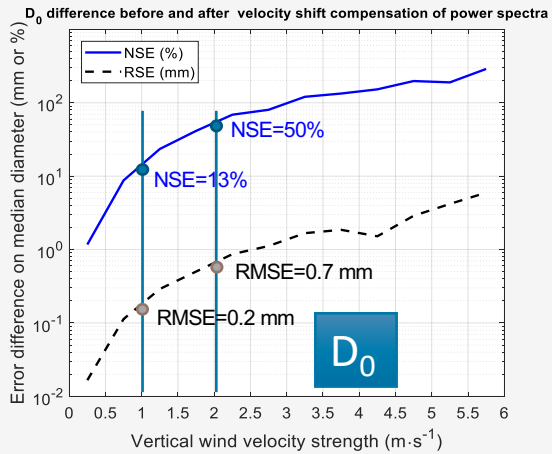
– 1 min averages of wind velocity

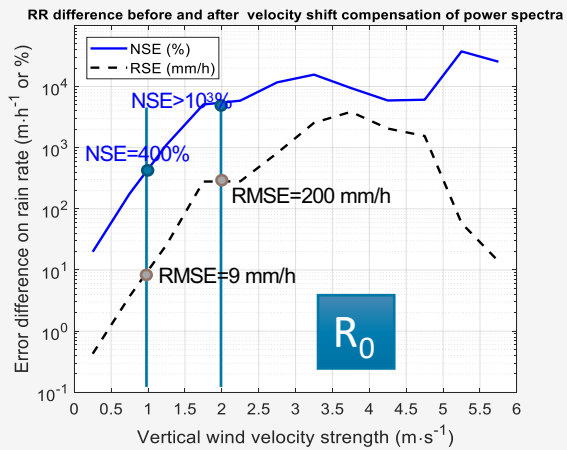
Examples point out a reasonable qualitative correlation between the MRR characteristic velocity and wind profiler velocity

# Vertical wind estimation from MRR data

## MRR corrected with UHF/S band profile vs. Uncorrected MRR



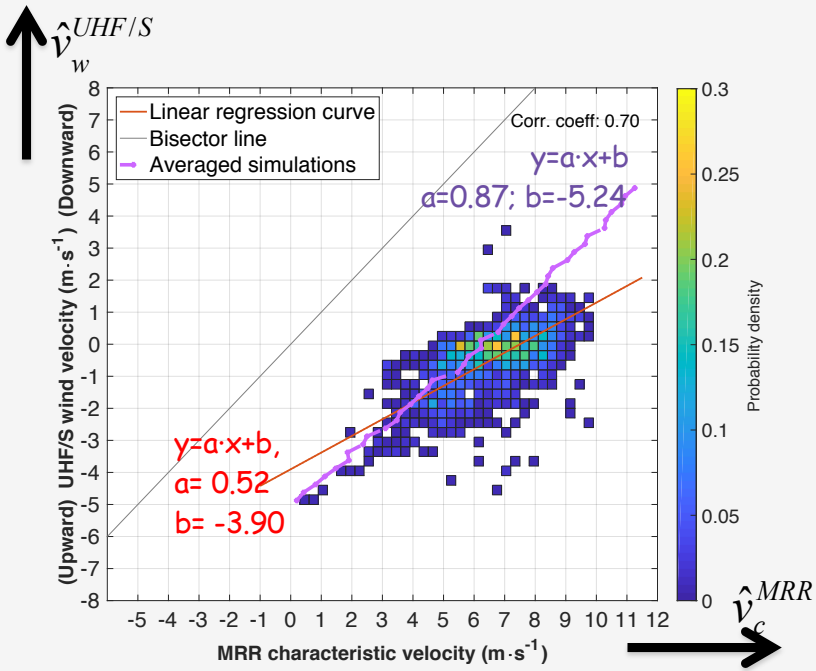

Updraft→$N^U < N^C$ for D<2mm, viceversa for D>2

Downdtraft→$N^U > N^C$ for D<2mm, viceversa for D>2

A vertical wind as 1 m/s produces a ~10% bias in $D_0$

A wind as low as 0.5 m/s is enough to bias the rain rate of ~60%

# Comparison of MRR and wind profiler




$$\hat{v}_c^{MRR} = \frac{\int_{-\infty}^{\infty} v \cdot \eta(v) \cdot dv}{\int_{-\infty}^{\infty} \eta(v) \cdot dv} = \frac{\int_{-\infty}^{\infty} (v_f \pm v_w) \cdot \eta(v) \cdot dv}{\int_{-\infty}^{\infty} \eta(v) \cdot dv}$$

$v_f$: drop fall velocity
$v_w$: vertical wind velocity
$v$: *apparent Doppler velocity*
$v_c$: *characteristic velocity*
$\eta$: *spectral reflectivity density*

Selected are:

- 21.10% rain samples (LWP>0)
- 39.32% profiles among those of rain

Filtered out range gates with

- MRR Spectral width ≤ 1.28 $m^{-1}$ or
- Liquid water path ≤ 110 $g \cdot m^{-2}$

**Linear regression on measured data**

- y=a·x+b with a= 0.5201; b= -3.9015

**Averaged simulations**

- y=a·x+b with a=0.87; b=-5.2420

3934 simulations varying:

- wind velocity (m/s) in [- 5, 5] , Wind std. (m/s) in [0, 1]
- DSD parameters $N_w$ ($m^{-3}$*$mm^{-1}$), $D_0$(mm), $\mu$ in [10^3 10^5], [0.5, 3.5], [-1 5], respectively

Correlation coefficient is quite high (0.7)

Simulations and measurements do not agree in terms of slope.

- The effect of wind could differently impact the spectral component of MRR spectra and then on the MRR characteristic velocity.
- The model of drop's terminal velocity in stagnant air used could not be strictly valid anymore in turbulent situations.

# Vertical wind estimation from MRR data

**Method 1 (reference**

$$\hat{v}_w(h) = a\hat{v}_c^{MRR}(h) + b$$

with

a=0.52; b=-3.9

**Method 2**

$$\hat{v}_w(h) = \hat{v}_c^{MRR}(h) - \hat{v}_f(h)$$

with

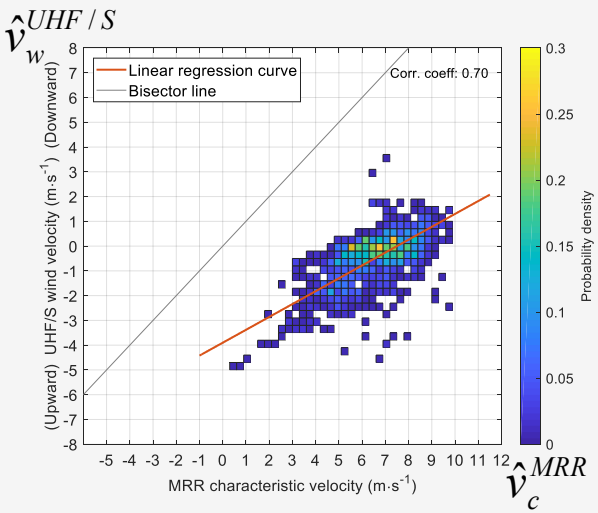
$$\hat{v}_f(h) = \hat{v}_c^{MRR}(h_m) = const$$

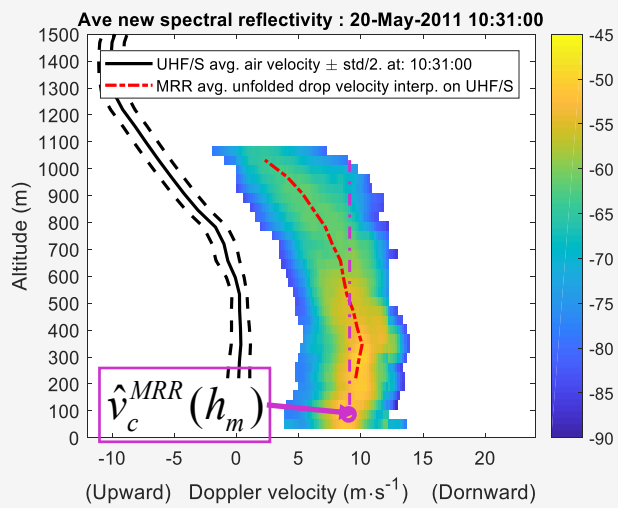
**Method 3**

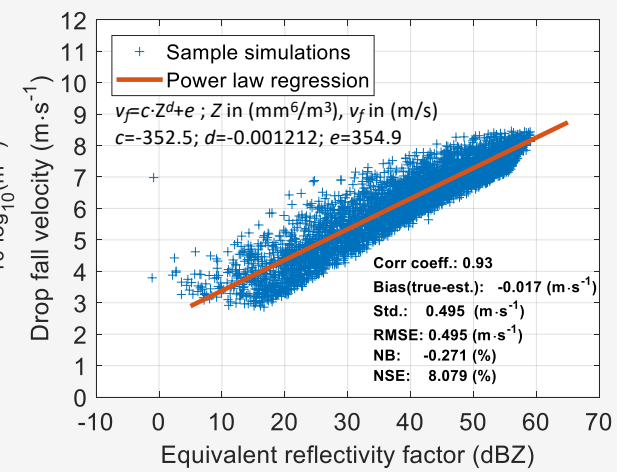
$$\hat{v}_w(h) = \hat{v}_c^{MRR}(h) - \hat{v}_f(h)$$

with

$$\hat{v}_f(h) = c[Z(h)]^d + d$$



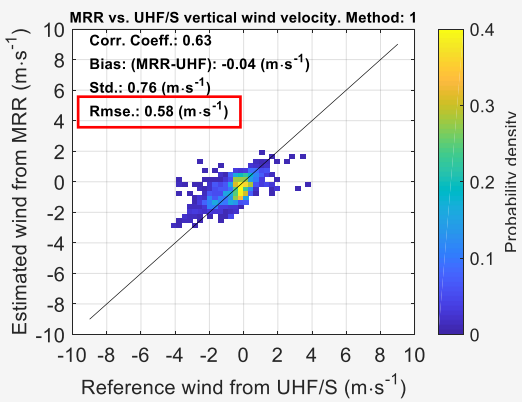



# Vertical wind estimation from MRR data

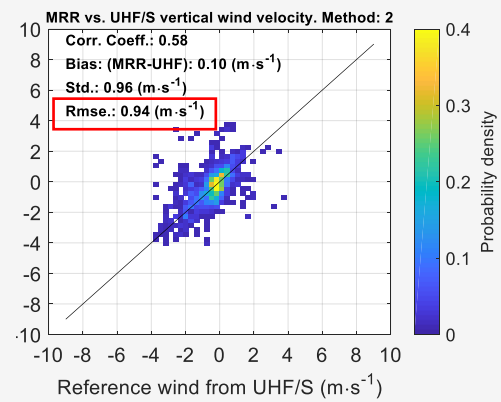
## Method 1

$$\hat{v}_w(h) = 0.52\hat{v}_c^{MRR}(h)\text{-}3.9$$



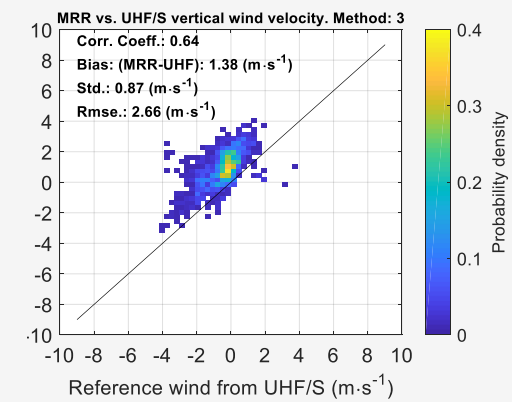

## Method 2

$$\hat{v}_w(h) = \hat{v}_c^{MRR}(h) - \hat{v}_c^{MRR}(h_m)$$




## Method 3

$$\hat{v}_w(h) = \hat{v}_c^{MRR}(h) - c[Z(h)]^d + d$$




| ¤ | Skill·scores·for·vertical·wind·orientation·estimation·¤ | | | | | |
|---|---|---|---|---|---|---|
| ¤ | PC·(%)¶ [0,·100]¤ | FD·(%)¶ [0,·100]¤ | POD·(%)¶ [0,·100]¤ | FAR·(%)¶ [0,·100]¤ | CSI¶ [0,·1]¤ | ETS¶ [-1/3,·1]¤ |
| **Method·1¤** | 72.09¤ | 16.42¤ | 47.62¤ | 42.36¤ | 0.35¤ | 0.20¤ |
| **Method·2¤** | 73.52¤ | 16.42¤ | 68.05¤ | 42.76¤ | 0.45¤ | 0.27¤ |
| **Method·3¤** | 48.60¤ | 74.54¤ | 98.32¤ | 61.96¤ | 0.38¤ | 0.09¤ |

**Method 2**

**does not require to fix a-priori coefficients**

**performs well in terms of skill score indexes of wind orientation**

# Using disdrometer to evaluate DPR product in Italy

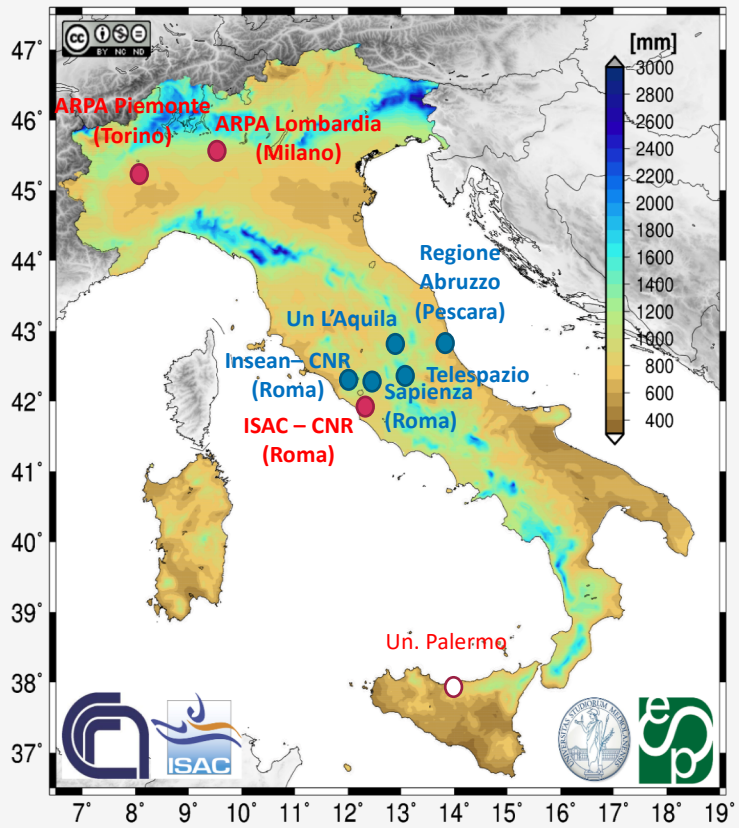
1. Disdrometers are instruments devised to pointwise estimate of Drop Size Distribution.
2. With respect to raingauges, they provide richer information, prompt estimation (interesting for light rain), etc, but, apart from campaigns, measurements are sparser that raingauge measurements
3. There are not standards for calibration (performed by manufactures, except 2DVD), or “data quality”.
4. In Italy there is growing number of laser disdrometers. They are not networked, are from different vendors , managed by independent bodies, deployed for a limited time.
5. We start using a subset of disdrometer to evaluate DPR products. This adds to the several GPM validation studies already published (Petracca et al. JHM 2018, D’Adderio et al. JHM 2018 **poster 248b**, Chiaravalloti et al. Atmospheric Research 2018, Caracciolo, Atmospheric Research 2018).
6. A few overpasses are available: Considering a 0.1° grid, total are 373÷799, thos with R>1.5mm/h are 1 ÷ 86. Resulting DPR coverage is not uniform in space

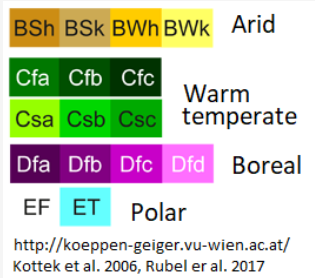
# Available disdrometers in Italy

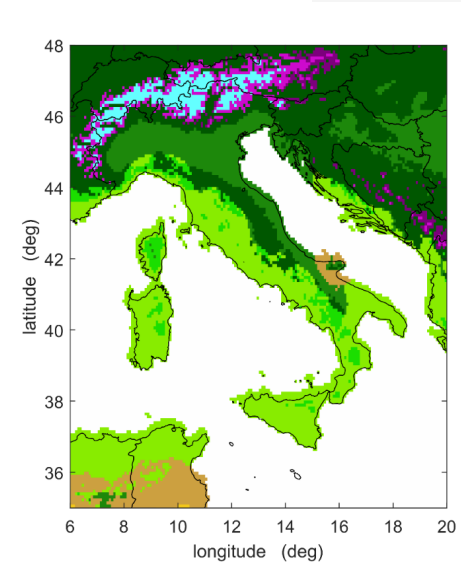
- HyMeX SOP 1
  Central Italy
  Sept-Nov 2012
  - 2DVD,
  - APUs (OTT Parsivel 2)
  - Metek Micro Rain Radar

- Disdrometer installations for long term measurements
  - Thies Clima LPM,
  - OTT Parsivel
  - OTT Parisvel2

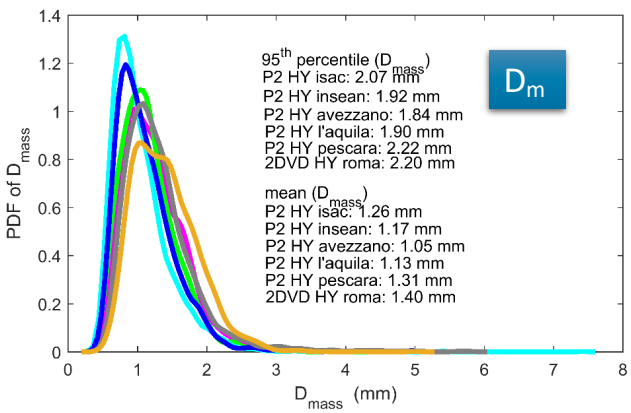
Need to consider diversity of sites and instruments

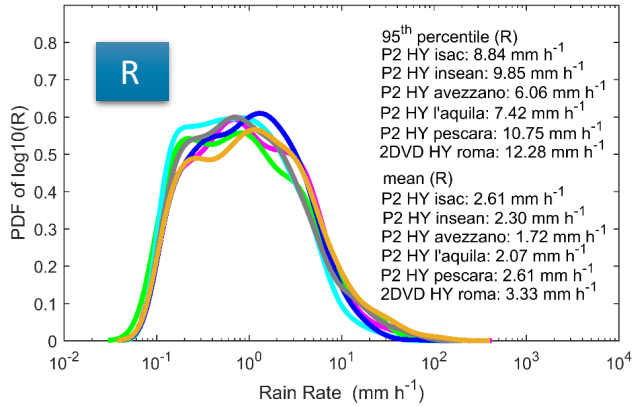


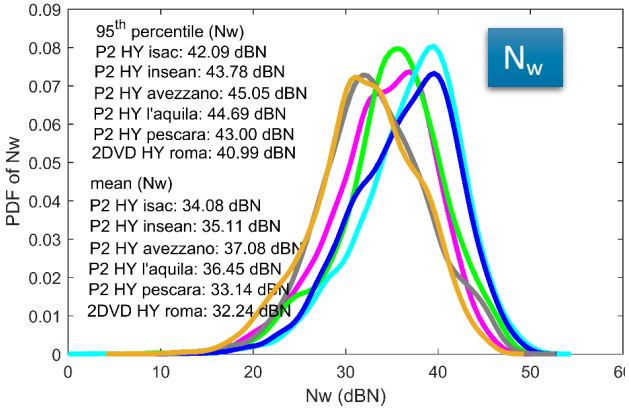



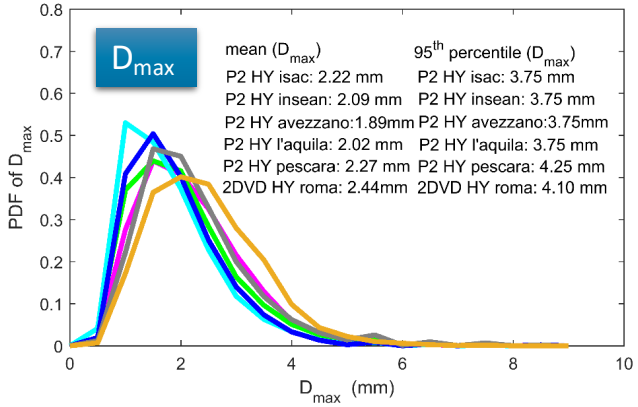



# HyMeX SOP1: 2DVD + APUs



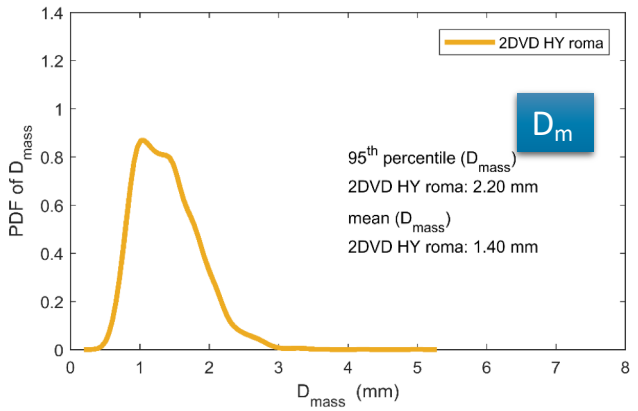



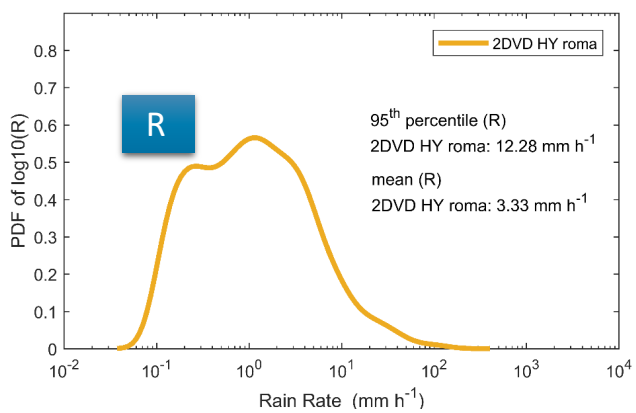


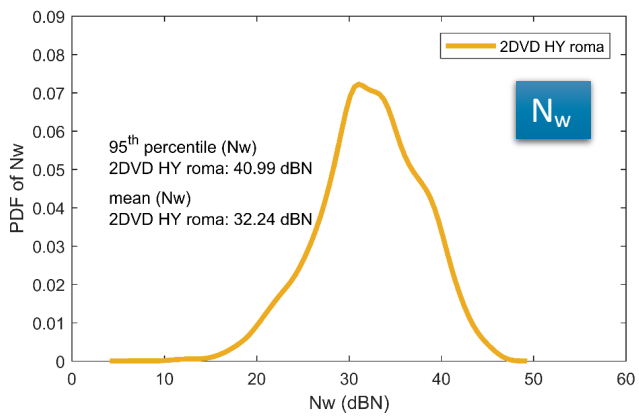



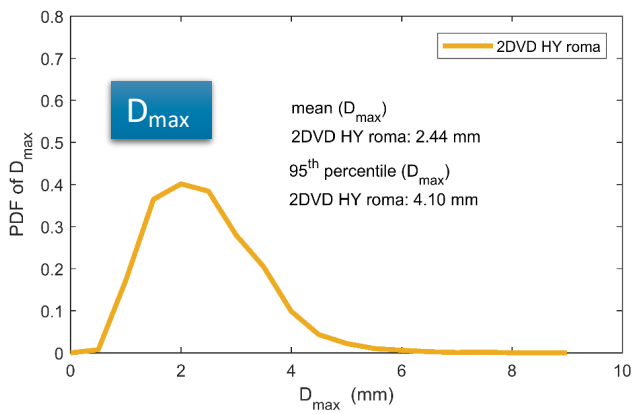

*Data are collected in the the same time period.*
*2DVD and P2-isac and P2-insean are within 10 km. Higher R, $D_m$ and $D_{max}$ are found at 2DVD site.*

# HyMeX SOP1: 2DVD



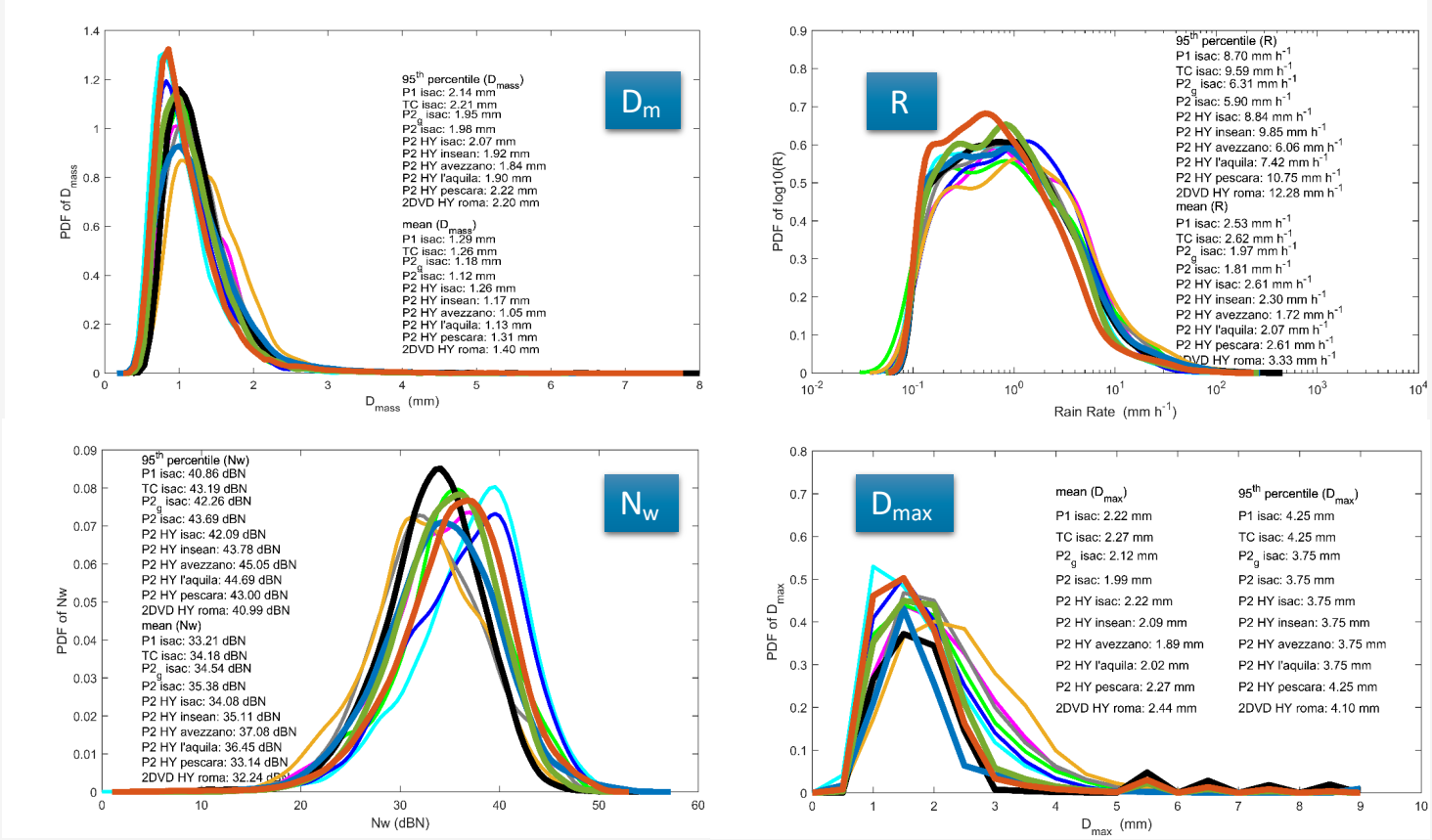



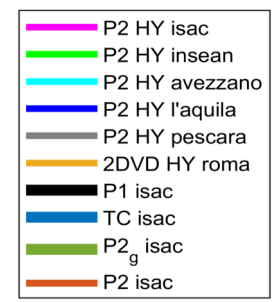




2DVD dataset was studied for adequacy of DSD model, particularly for the right tail (Adirosi et al. 2014, 2105, 2016) with respect to 2-parameter pdfs:

*"The Gamma distribution is ranked as first in fitting the data records, thus indicating that the probability distributions whose tails are exponentially bounded, i.e. light-tailed distributions, seem to be adequate to model the natural variability of DSDs. (…) the lognormal distribution is the best model in a significant number of cases (…) characterized by high values of the maximum diameter ($D_{max}$), rainfall rate ( R) and raindrop mass spectrum mean diameter ( $D_{mass}$), while the opposite is generally valid for the Weibull distribution."*

# All disdrometers




- What is the influence of the different type of disdrometer on retreved Nw, Dm?
- How can we separate differences due to instruments from that due to precipitation physics ?

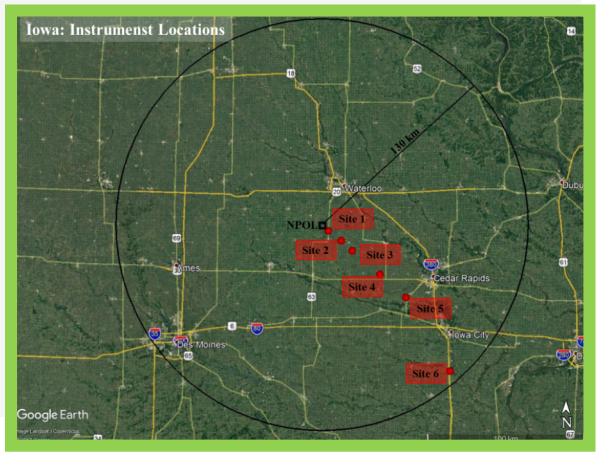
# Using disdrometers to establish radar algorithms (1/4)

> Due to the differences in hardware and software co-located disdrometers can sample the DSD differently.
> These disagreements produce differences in the integral rainfall parameters estimated from measured DSD, and the impact of the DSD disagreement varies from one parameter to another.

**Objectives:**

1. Precipitation and specific attenuation estimates from dual-polarization radar measurements obtained from DSDs collected by different types of disdrometers
2. Investigate at what extent dual-polarization radar algorithms derived from experimental DSD datasets are influenced by the different error structure of the diverse type of disdrometers

| | dataset name | type of device | location | Time period |
|---|---|---|---|---|
| Long time series | ISAC-CNR P1 | P1 | Rome, IT | Jun.2010–Mar.2016 |
| Long time series | ISAC-CNR TC | TC | Rome, IT | Sep.2012–Nov.2017 |
| 2-month field campaign | HyMeX P2 | P2 | Rome, IT | Sep.-Nov. 2012 |
| 2-month field campaign | HyMeX 2DVD | 2DVD | Rome, IT | Sep.-Nov. 2012 |
| 2-month field campaign | IFloodS 2DVD | 2DVD | Iowa, USA | Apr.-Jun. 2013 |
| 2-month field campaign | IFloodS P2 | P2 | Iowa, USA | Apr.-Jun. 2013 |



# Using disdrometers to establish radar algorithms (2/4)

### Measured Drop size distribution

$$N^{P1,P2;TC}(D_i)\ \frac{1}{A^{P1,P2,TC}\ \Delta t\ \Delta D_i^{P1,P2,TC}} \sum_{j=1}^{C_v^{P1,P2,TC}} \frac{n_{j,i}}{v_j};$$

$$N^{2DVD}(D_i) = \frac{1}{A^{2DVD}\Delta t\ \Delta D_i^{2DVD}} \sum_{k=1}^{M_i} \frac{1}{v_i^{2DVD}}$$

- A = measuring area, Δt = time interval, ΔD = width of the diameter classes
- nj,i = number of drops measured in the bin (i,j), Mi = total number of drops detected in Δt, $C_v$ number of fall velocity classes
- v = terminal fall velocity (Atlas et al., 1973, Rev. Geophys, 11, 1-35 )

### Data quality analysis

All the datasets considered in this study underwent the same procedure of post-processing and filtering.

- ✓ Fall velocity filter (Tokay et al. 2001)
- ✓ Minimum 4 adiacent filled bins
- ✓ No «isolate» rainy minutes (at least 5 minutes of rain in 2 hours)
- ✓ $D_{max} \cong 10\ mm$
- ✓ R < 300 mm $h^{-1}$ and $Z_{rayleigh}$ < 55 dBz

$$\mathrm{R} = 6\,\pi\,10^{-4} \sum_{D_{min}}^{D_{max}} v(D)N(D\ )D^3\ dD$$

$$Z_{rayleigh} = \sum_{D_{min}}^{D_{max}} N(D\ )D^6\ dD$$

Electromagnetic simulation (**T-matrix method**) to compute at 2.85 (S-band), 5.6 (C-band) and 9.375 (X-band) GHz

$$Z_{h,v} = \frac{4\,\lambda^4}{\pi^4\,|K_w|^2} \int \left|s_{h,v}(D)\right|^2 N(D)dD$$

$$K_{dp} = \frac{180\,\lambda}{\pi} \int [f_h(D) - f_v(D)]\ N(D)dD$$

$$Z_{dr} = 10\ log_{10}(Z_h/Z_v)$$

$$a_{h,v} = 8.686\,\lambda \int Im\left[f_{h,v}(D)\right] N(D)dD$$

- λ = wavelength, and Kw = dielectric constant of water
- $s_{h,v}$ = backscattering amplitudes, and $f_{h,v}$ = forward scattering amplitudes

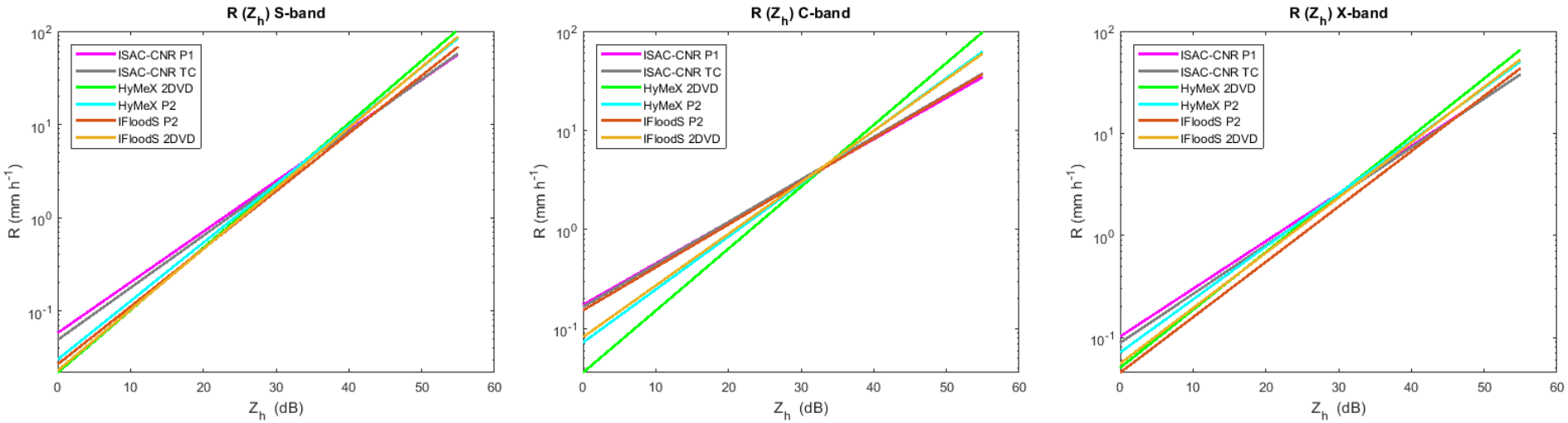
**For each considered dataset a non linear regression** has been applied to obtain the coefficients of the following polarimetric radar algorithms:

$$a_h = \alpha_1\,K_{dp} \qquad R = \alpha_3\,{Z_h}^{\beta_3} \qquad R = \alpha_5\,K_{dp}$$

$$a_d = \alpha_2\,K_{dp} \qquad R = \alpha_4\,{Z_h}^{\beta_4}\,{Z_{dr}}^{\gamma_4} \qquad R = \alpha_6\,{Z_{dr}}^{\beta_6}\,{K_{dp}}^{\gamma_6}$$

# Using disdrometers to establish radar algorithms (3/4)

R($Z_h$) at S-, C- and X-bands obtained using different datasets of measured DSD




To **quantify** the effect of disdrometer type, radar algorithms derived from different measured DSD datasets a pairwise comparison is performed in terms of Normalized Mean Absolute Error (NMAE)

$$NMAE = \frac{\overline{|x_i - y_i|}}{\bar{x}}\text{; x and y estimates derived from two different disdrometer dataset.}$$

# Using disdrometers to establish radar algorithms (4/4)

**S-band**

| | ISAC-CNR P1 vs ISAC-CNR TC | ISAC-CNR TCHy* vs HyMeX P2 | HyMeX 2DVD vs HyMeX P2 | IFloodS 2DVD vs IFloodS P2 |
|---|---|---|---|---|
| $R = \alpha_3 Z_h^{\beta 3}$ | 2% | 15% | 14% | 19% |
| $R = \alpha_4 Z_h^{\beta 4} Z_{dr}^{\gamma 4}$ | 6% | 3% | 17% | 10% |
| $R = \alpha_5 K_{dp}$ | 5% | 9% | 19% | 13% |
| $R = \alpha_6 Z_{dr}^{\beta 6} K_{dp}^{\gamma 6}$ | 5% | 1% | 7% | 6% |

**Values of NMAE (in %)** obtained comparing by pairs the parameters estimated through the weather radar algorithm established from 1-min DSDs collected by the **two different devices**.

**C-band**

| | ISAC-CNR P1 vs ISAC-CNR TC | ISAC-CNR TCHy* vs HyMeX P2 | HyMeX 2DVD vs HyMeX P2 | IFloodS 2DVD vs IFloodS P2 |
|---|---|---|---|---|
| $R = \alpha_3 Z_h^{\beta 3}$ | 6% | 28% | 28% | 29% |
| $R = \alpha_4 Z_h^{\beta 4} Z_{dr}^{\gamma 4}$ | 4% | 13% | 16% | 6% |
| $R = \alpha_5 K_{dp}$ | 9% | 12% | 14% | 7% |
| $R = \alpha_6 Z_{dr}^{\beta 6} K_{dp}^{\gamma 6}$ | 5% | 1% | 6% | 5% |

**X-band**

| | ISAC-CNR P1 vs ISAC-CNR TC | ISAC-CNR TCHy* vs HyMeX P2 | HyMeX 2DVD vs HyMeX P2 | IFloodS 2DVD vs IFloodS P2 |
|---|---|---|---|---|
| $R = \alpha_3 Z_h^{\beta 3}$ | 2% | 18% | 9% | 18% |
| $R = \alpha_4 Z_h^{\beta 4} Z_{dr}^{\gamma 4}$ | 10% | 3% | 7% | 6% |
| $R = \alpha_5 K_{dp}$ | 5% | 6% | 10% | 6% |
| $R = \alpha_6 Z_{dr}^{\beta 6} K_{dp}^{\gamma 6}$ | 4% | 2% | 8% | 2% |

**Lower is the values of NMAE** and better is the agreement between the estimators, or in other words, **lower is the influence of the disdrometer type** on the weather radar algorithm.

* ISAC-CNR TCHy is a subset of the long term dataset ISAC-CNR TC that includes only the months of the HyMeX SOP1 field campaign.

# Using disdrometers to establish radar algorithms (4/4)

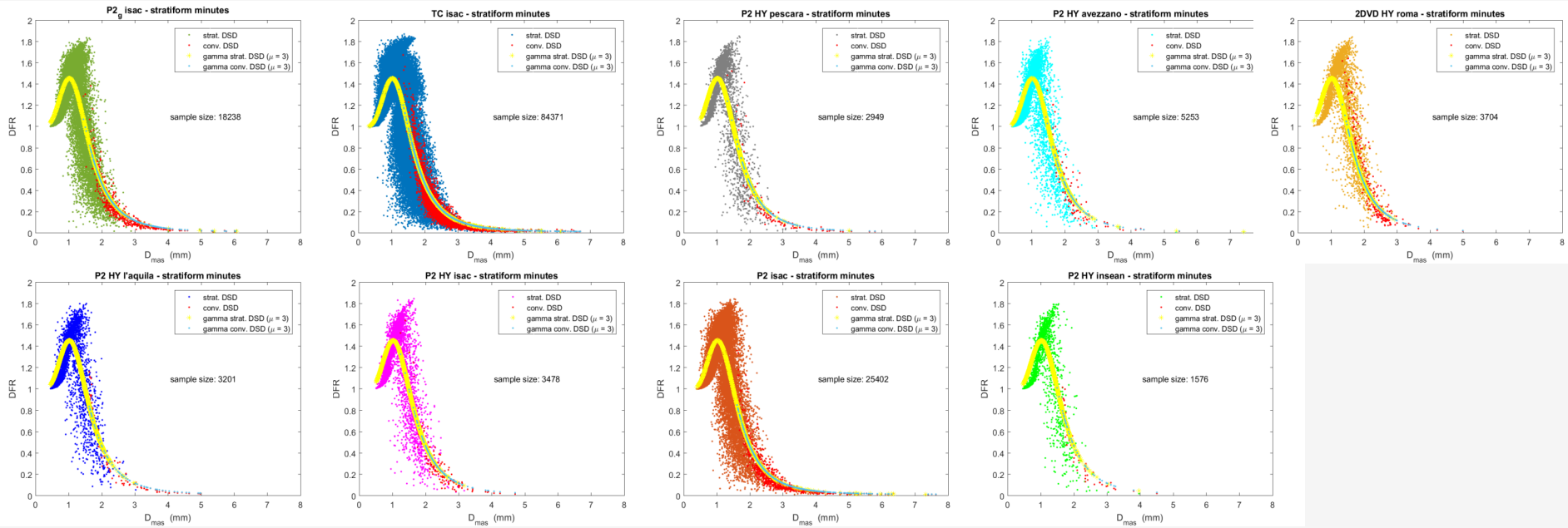
- the comparison of algorithms obtained from laser disdrometers (Parsivel , Parsivel2 or TC) gives an error <10% for all the relations and frequencies (except for very few exception).
- the agreement in terms of radar algorithm obtained with P2 and 2DVD is a bit worse, particularly at S- and C-band: differences can reach 30% at C-band for $R(Z_h)$.
- limiting the comparison to moderate rainfall ($2.5\ mmh^{-1} < R < 10\ mmh^{-1}$) the disagreement between 2DVD and P2 decreases at 10%;
- it is confirmed that dual-polarization rain rate estimators seem to be less sensitive to the disdrometer type with respect to the $R(Z_h)$ relation.

In some conditions, the use of a low-cost laser disdrometer to establish long-term climatological radar algorithms does not produce considerable differences with respect to more accurate devices such as the 2DVD. Instead more accurate microphysical analysis can benefit by the used of more sophisticated 2DVD.

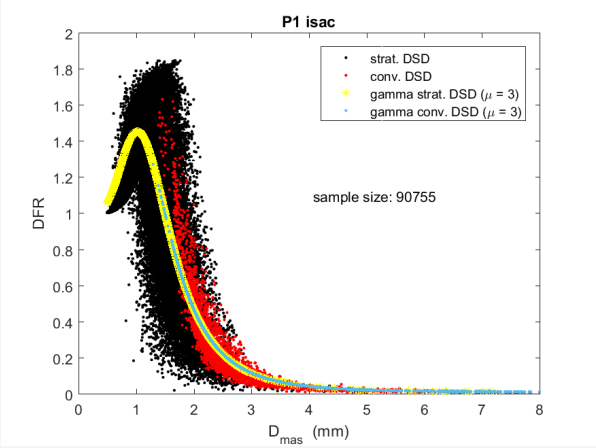
Adirosi, E.; Roberto, N.; Montopoli, M.; Gorgucci, E.; Baldini, L. Influence of Disdrometer Type on Weather Radar Algorithms from Measured DSD: Application to Italian Climatology. *Atmosphere* **2018**, *9*, 360.

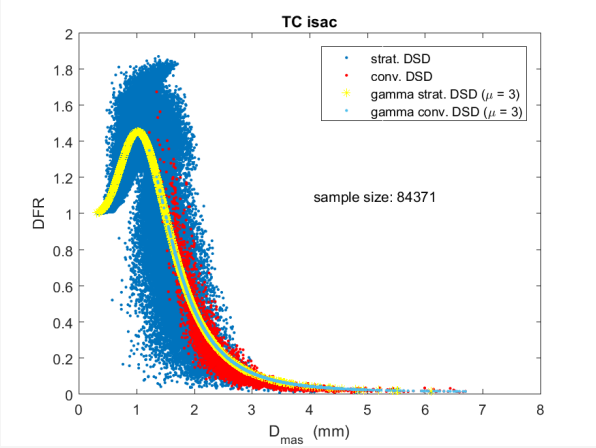
# Using disdrometers to evaluate DFR-$D_m$ relation

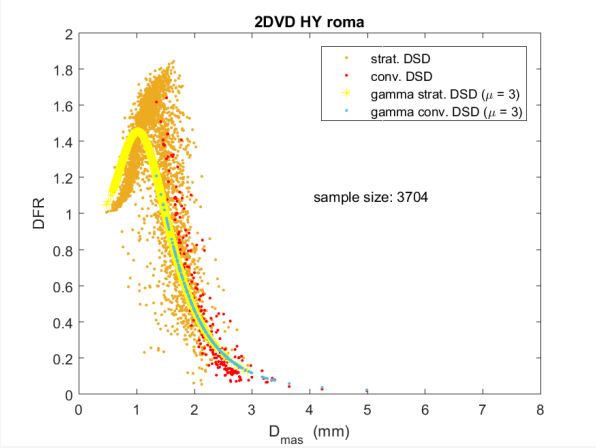
Simulations with T = 20°, drop shape model Beard and Chuang (1987), S/C partitioning Thurai et al. (2010).



# Using disdrometers to evaluate DFR-$D_m$ relation



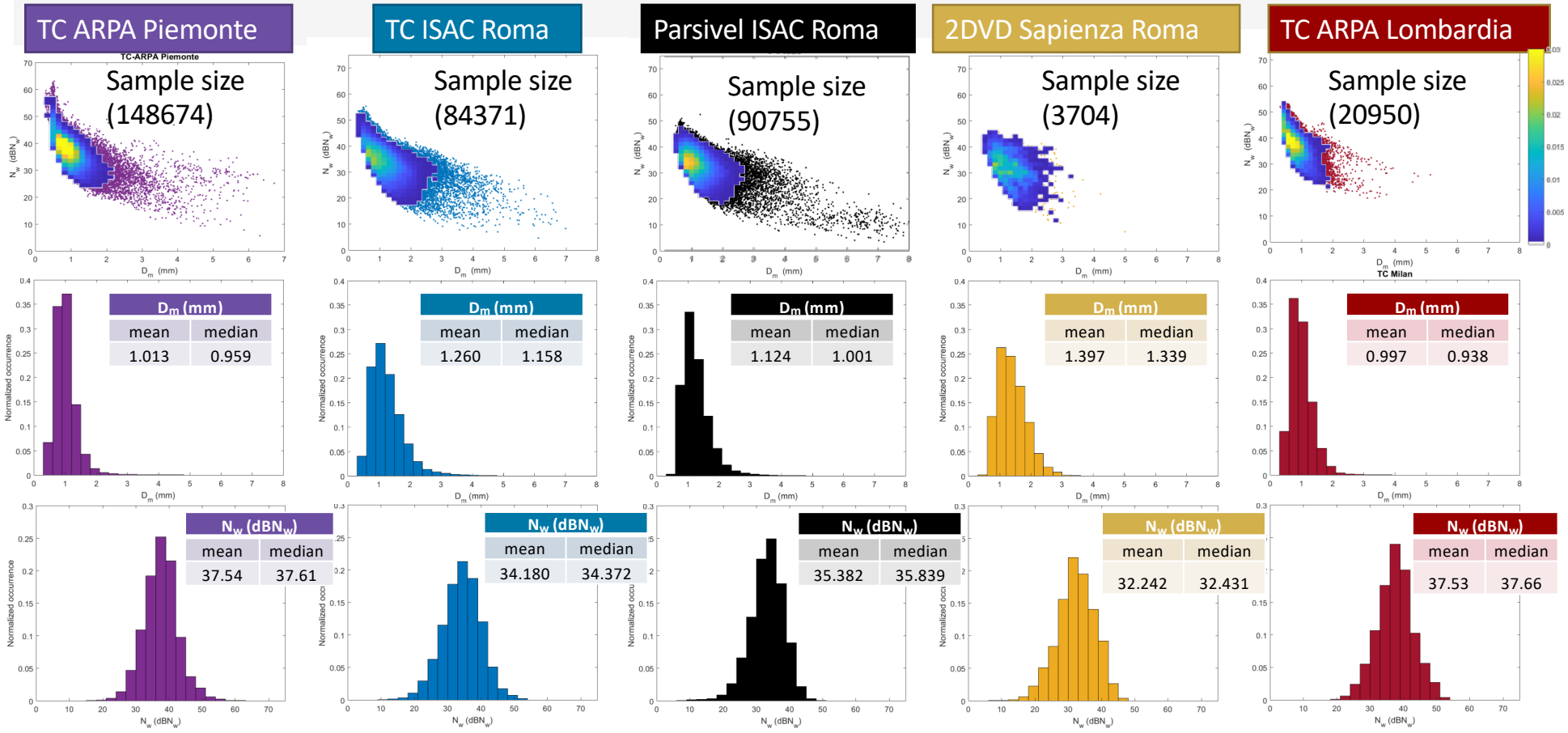




Single site (ROME)
NMAE between disdrometer DFR and gamma DFR (μ = 3).
DFR dimensionless.
Results depends on the the type of disdrometer used (laser/video), reagardless of strat/conv

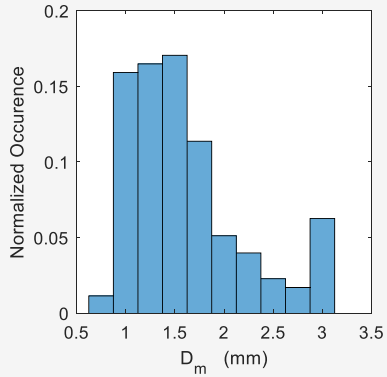
| | NMAE | | | *Sample size* | | |
|---|---|---|---|---|---|---|
| | **all** | **strat** | **conv** | *all* | *strat* | *conv* |
| **P1** | **0.166** | **0.164** | **0.246** | *90755* | *85630 (95.8%)* | *3769 (4.2%)* |
| **TC** | **0.156** | **0.154** | **0.248** | *84371* | *78924 95.3%* | *3932 4.7%* |
| **2DVD HY** | **0.214** | **0.209** | **0.311** | *3704* | *3343 (94.4%)* | *236 (6.6%)* |

# $N_w$ vs $D_m$ from disdrometer data in Italy

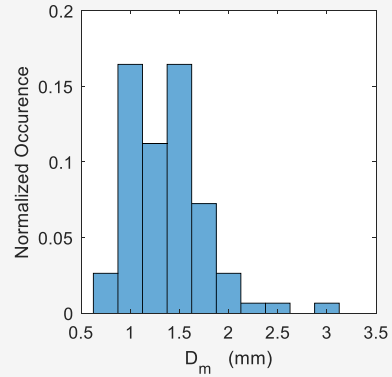


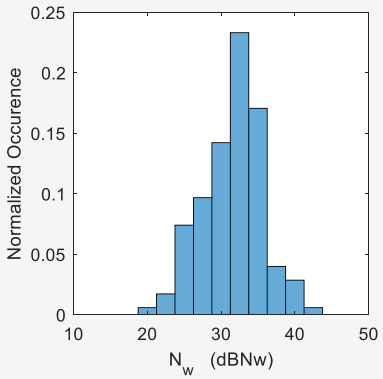
# Analysis of DPR (MS) overpasses

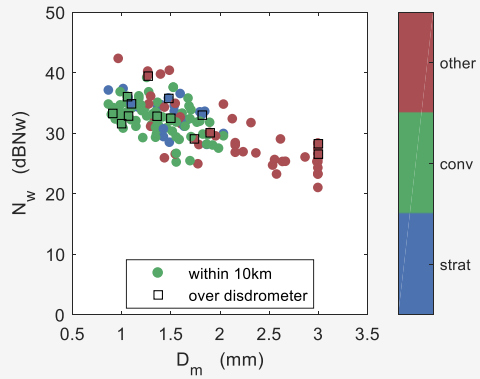
**ARPA Piemonte**
**14** overpasses with R>1.5mm/h within 10km from disdrometer:
Strat: 6
Conv: 6
Other: 5

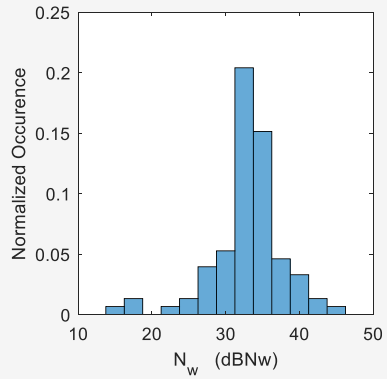


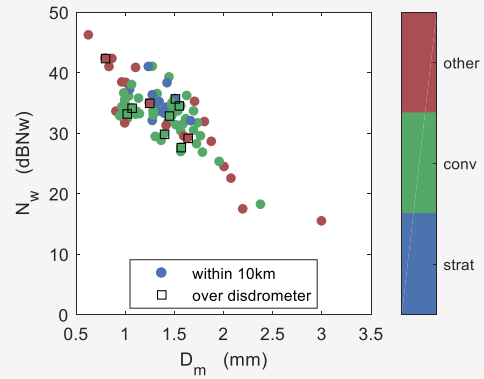

**ISAC Rome**
**12** overpasses with R>1.5mm/h within 10km from disdrometer:
Strat:1
Conv: 6
Other: 3



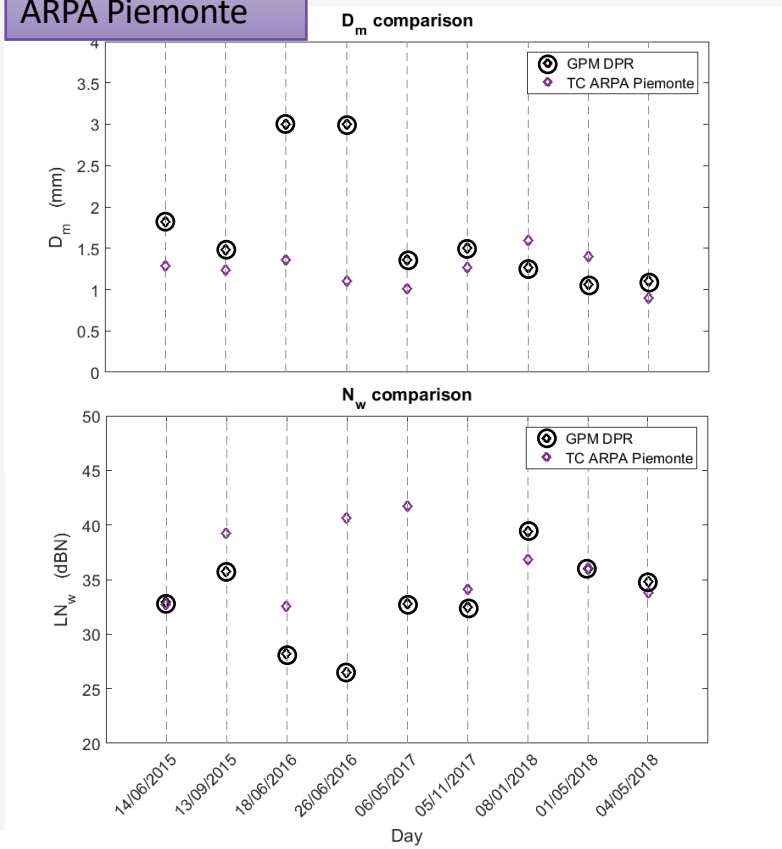



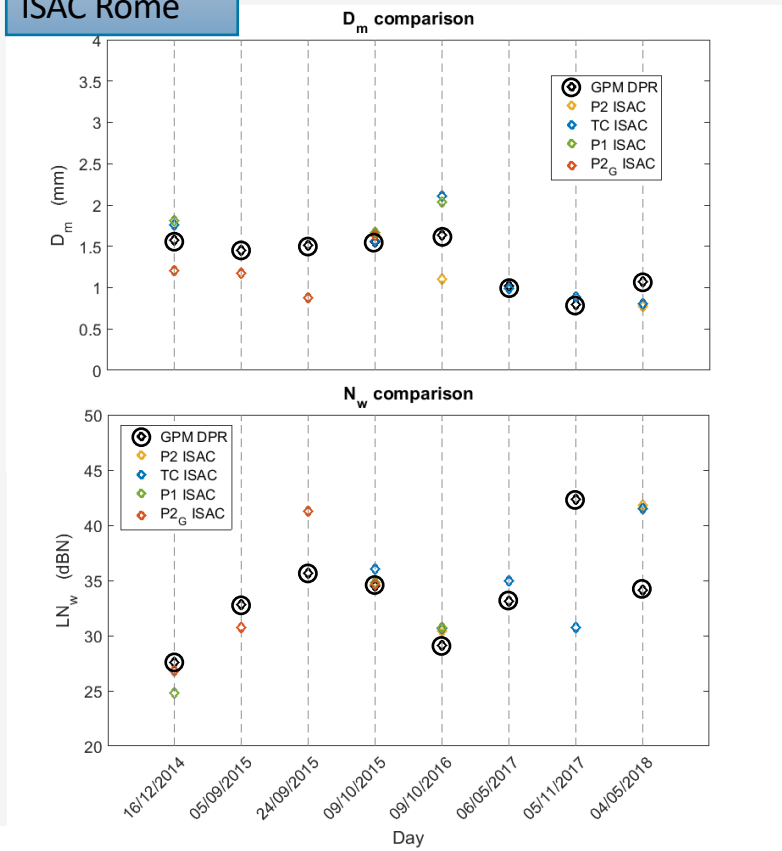



# Analysis of DPR overpasses

ARPA Piemonte




ISAC Rome



# Analysis of DPR (MS) overpasses

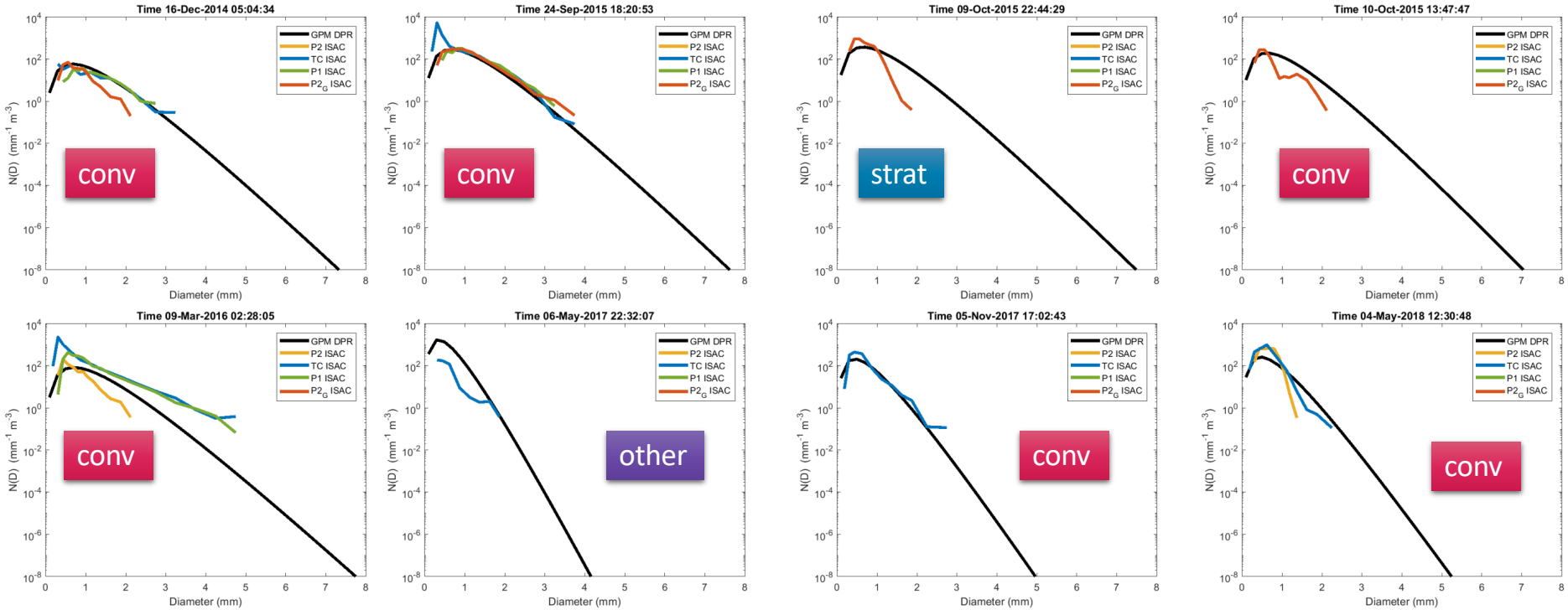
ARPA Piemonte

| Overpasses date | differences between GPM DPR and TC data and over Turin area | | |
|---|---|---|---|
| | $D_m$ (mm) | $N_w$ ($dBN_w$) | S/C |
| 2015 06 14 | 0.53 | 0.26 | strat |
| 2015 09 13 | 0.24 | -3.53 | strat |
| 2016 06 18 | 1.64 | -4.35 | other |
| 2016 06 26 | 1.89 | -14.15 | other |
| 2017 11 05 | 0.34 | -8.91 | conv |
| 2017 05 06 | 0.23 | -1.62 | conv |
| 2018 01 08 | -0.32 | 2.56 | other |
| 2018 05 01 | -0.33 | -0.04 | conv |
| 2018 05 04 | 0.20 | 1.06 | strat |

ISAC Rome

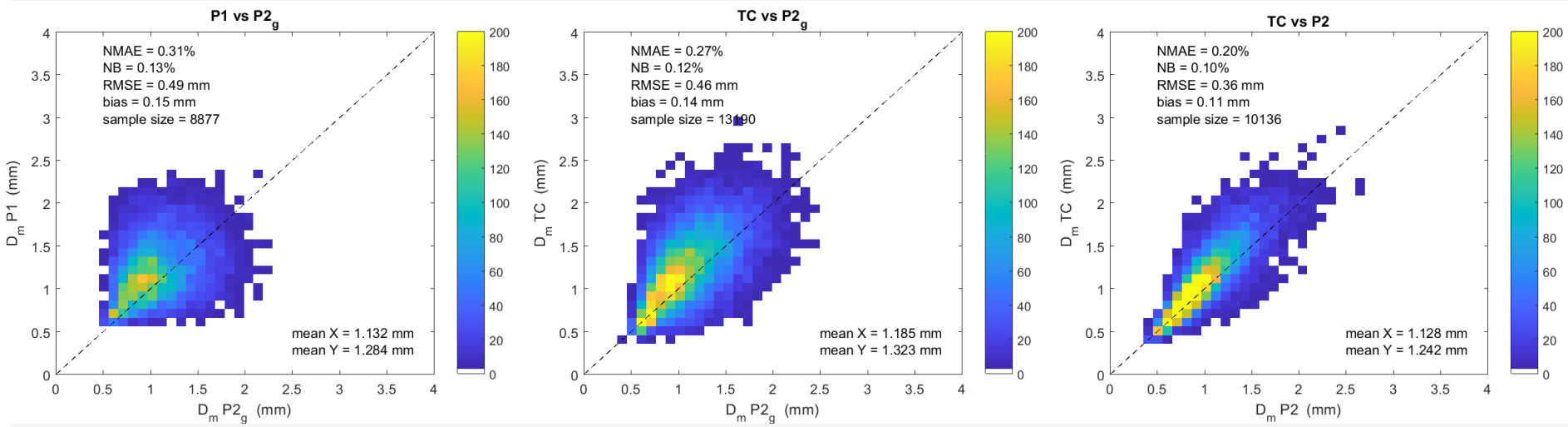
| Overpasses date | mean differences between GPM DPR and disdrometer available in Rome | | |
|---|---|---|---|
| | $D_m$ (mm) | $N_w$ ($dBN_w$) | S/C |
| 2014 12 16 | -0.02 | 2.11 | conv |
| 2015 10 10 | 0.27 | 2.04 | conv |
| 2015 10 09 | 0.63 | -5.64 | strat |
| 2015 09 24 | -0.07 | -0.67 | conv |
| 2016 03 09 | -0.10 | -1.48 | other |
| 2017 11 05 | 0.03 | -1.80 | conv |
| 2017 05 06 | -0.08 | 11.56 | other |
| 2018 05 04 | 0.27 | -7.57 | conv |

# Analysis of DPR (MS) overpasses



# Instrumental biases in $D_m$ estimates ?

Coincident measurements collected at ISAC Roma (1 min)




***Literature references:***

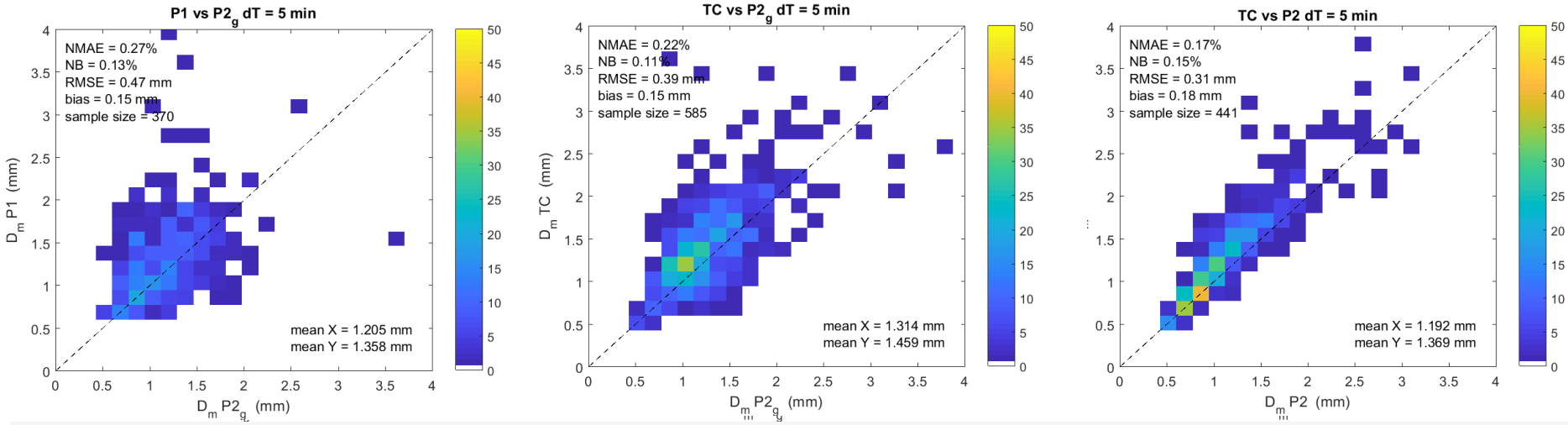
P2 understimates with respect to P1 by ~0.08mm (Tokay et al. JTECH 2014, table 2)

2DVD underestimates with respect to P1 by ~0.13mm (Tokay et al. JTECH 2013, table 2).

APUs vs 2DVD: Ifloods data shows negligible differences in mean($D_m$) between considered APU-2DVD pairs, although there are differences in maximum($D_m$)

# Instrumental biases in $D_m$ estimates ?

Coincident measurements collected at ISAC Roma (5 minute)

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P2 understimates with respect to P1 by ~0.08mm (Tokay et al. JTECH 2014, table 2)

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APUs vs 2DVD: Ifloods data shows negligible differences in mean($D_m$) between considered APU-2DVD pairs, although there are differences in maximum($D_m$)

# Techniques for validating DPR Level 2 products in Italy
# **Conclusions**

Validation of DPR rain retrievals using the SNM method

⇒ **An alternate method shed light on dependencies of algorithms' performance on critical basic assumptions**

Micro Rain Radar: assessing the influence vertical wind

⇒**Estimate vertical wind improves the usefulness of existing MRR archives for GV purposes has been provided**

Using disdrometer to evaluate DPR product in Italy

⇒ **Disdrometers can play a role in GPM statistical validation in spite of small sample size and diversity of instruments**