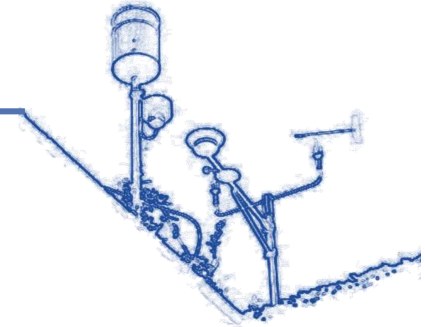
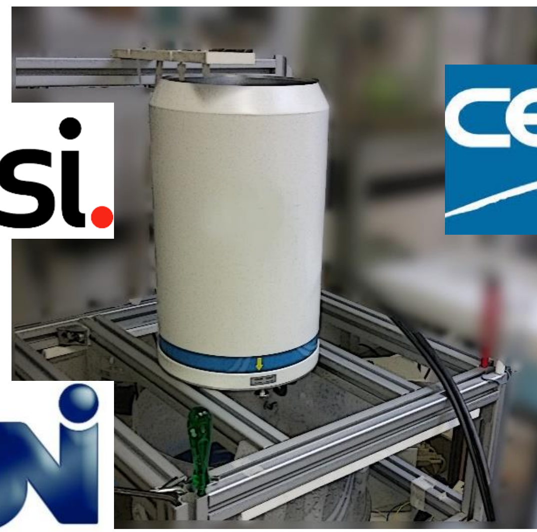
JMA/WMO Workshop on Quality Management of Surface Observations
RA II WIGOS Project
Tokyo, Japan, 19-23 March 2018



Accuracy of precipitation measurements, instrument calibration and techniques for data correction and interpretation

Catching-type Rain Gauges: Standards and Performance



Mattia Stagnaro
Luca G. Lanza
Arianna Cauteruccio

University of Genova - DICCA
Dept of Civil, Chemical and Environmental Engineering

Tokyo, 22 March 2018

WMO/CIMO Lead Centre "B. Castelli"
on Precipitation Intensity

WMO

Contents

➢ Rain Gauges

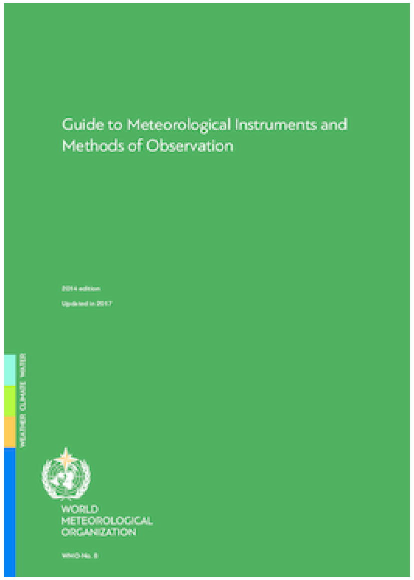
Catching type Rain Gauges

- ✓ Tipping Bucket Rain Gauge (TBRG)
- ✓ Weighing Gauge (WG)
- ✓ Drop Counter

NON-Catching type Rain Gauges

- ✓ Disdrometer
- ✓ Optical
- ✓ Radar
- ✓ Impact

➢ WMO/CIMO guide



Guide to Meteorological Instruments and Methods of Observation: (CIMO guide)

WMO- No. 8 (2014 – updated 2017)

CHAPTER 6. MEASUREMENT OF PRECIPITATION

Annex 6.C:

Provides **principles** and **requirements** for the rain gauges calibration system and calibration procedures.

In addition, describes the procedure for **data interpretation** of the results in terms of relative error, and the indication of the ±5% limit on the graph to highlights the WMO requirements

WORLD
METEOROLOGICAL
ORGANIZATION

BS 7843–3:2012: Acquisition and management of meteorological precipitation data from a gauge network.
Part 3: Code of practice for the design and manufacture of storage and automatic collecting rain gauges.

A standard on the UK reference storage daily rain gauge and related aspects.
Calibration concepts are based on the ***CEN/TR 16469****.*
A classification is introduced only on Tipping Bucket gauges:

Class	Maximum Acceptable Deviation	
A	±5%	dynamically calibrated according to CEN/TR 16469:2012
B	10-15 mm/h	static calibration only

Weighing rain gauges should be calibrated accurately by the manufacturer

➢ Standards (Catching-Type)

UNI 11452:2012

HYDROMETRY – MEASUREMENT OF RAINFALL INTENSITY (LIQUID PRECIPITATION) : METROLOGICAL REQUIREMENTS AND TEST METHODS FOR CATCHING TYPE GAUGES

This standard defines the metrological requirements for rainfall intensity (liquid precipitation) gauges and establishes classification criteria based on the evaluation of measurement accuracy.

This standard is applicable irrespective of the measurement principle (i.e. physical principle on which measurement is based) and the technical and technological characteristics of the specific gauge.

The description of test procedures and equipment for calibration and metrological confirmation both in the laboratory and on-site, under steady flow conditions are provided for the catching type gauges only.

The various Classes shall be attributed to each rainfall intensity gauge, for the interval of rain intensity values where attribution of the Class is requested, according to the following requirements:

Class	Maximum Acceptable Deviation	Step response time (*)
A	±3%	< 1 min
B	±5%	< 1 min
C	±5%	≥ 1 min
	±10%	< 1 min
(*) Relevant for weighing gauges only		

$$e_{rel}\,(\%) = \frac{RI_{meas} - RI_{ref}}{RI_{ref}} \cdot 100$$

RI_{meas} Measured Rainfall Intensity

RI_{ref} Reference Rainfall Intensity

TC 318 – Hydrometry
WG 12 – Measurement of rainfall intensity

VARIABLE RI SIMULATOR (Laboratory)

RI simulator performance evaluation:

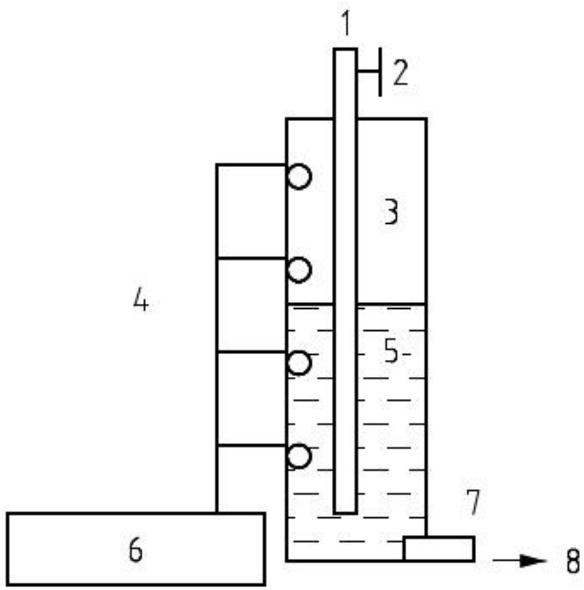
- Calibration of the generated RI (average of multiple realizations).
- Evaluation of the RI repeatability.
- Evaluation of the instrumental delays in executing the commands (start, stop, RI change)

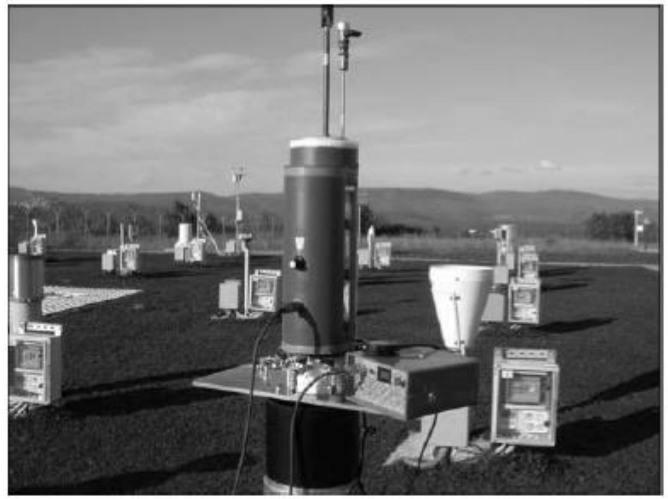
Operational range:	20 - 450 ml/min	
Trueness estimation:	max e_{avg}= 1 %	evaluated at 60 ml/min
Precision estimation:	max CV = 0.4%	evaluated at 20 ml/min
Time resolution:	Δt_{min}= 15 sec	(characteristic time < 200 ms)

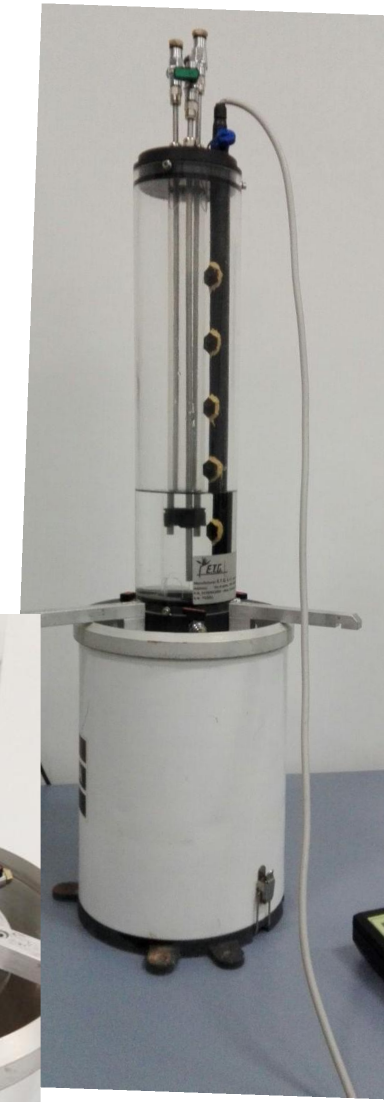
Calibration techniques (lab and field)

VARIABLE RI SIMULATOR (Field)

Man-portable device for calibration verification in field





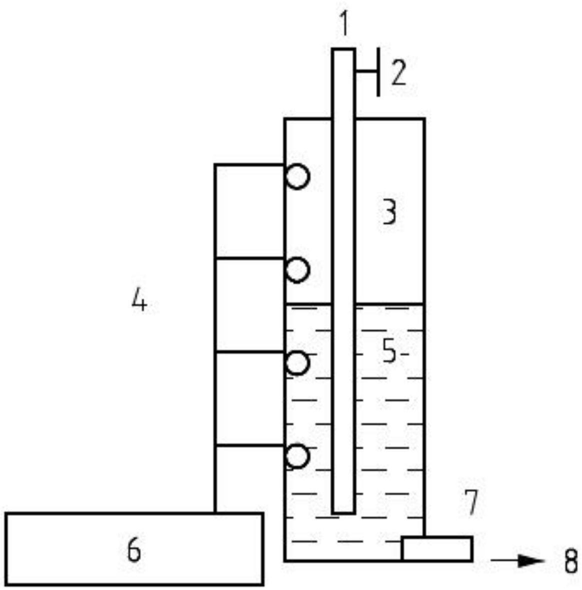


Key

1 air intake
2 tap
3 air
4 electrodes for emptying time
5 water
6 electronic timer
7 nozzle
8 I_{ref} (mm/h) = const

Stagi L. and Lanza, L.G. (2006)

VARIABLE RI SIMULATOR (Field)



Key
1 air intake
2 tap
3 air
4 electrodes for emptying time
5 water
6 electronic timer
7 nozzle
8 I_{ref} (mm/h) = const

- Verify the operational status of raingauges
- According to the raingauge collector size and the value of rainfall intensity chosen for the calibration, the suitable combination of air intakes and nozzles should be selected to generate the desired **constant flow**

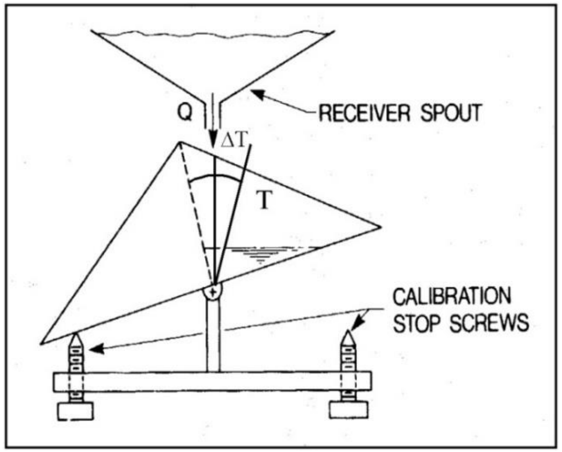
Stagi L. and Lanza, L.G. (2006)

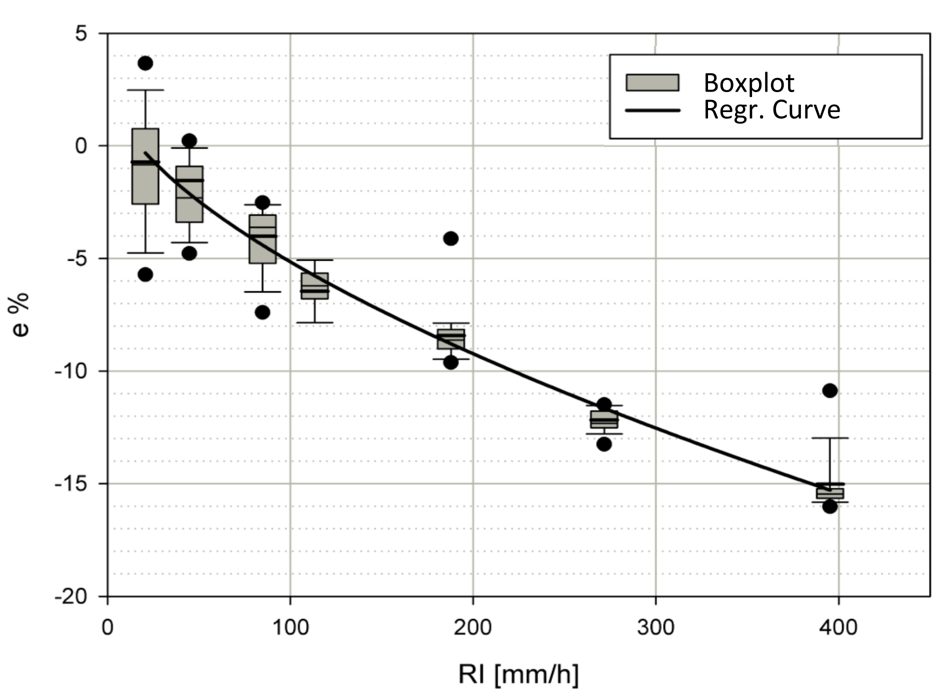
➢ Tipping-Bucket Rain Gauges

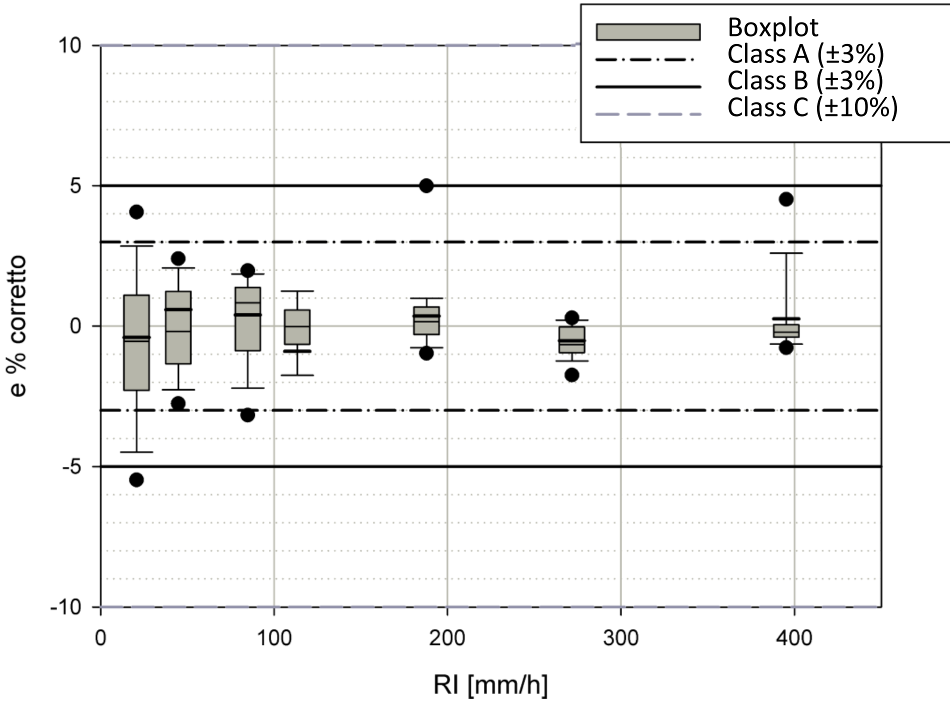
Main source of errors:

(a) The loss of water during the tipping action in heavy rain **SISTEMATIC MECHANICAL ERROR**

(b) The discontinuous nature of the record may not provide satisfactory data during light drizzle or very light rain. **SAMPLING ERROR**







THE SAMPLING ISSUE

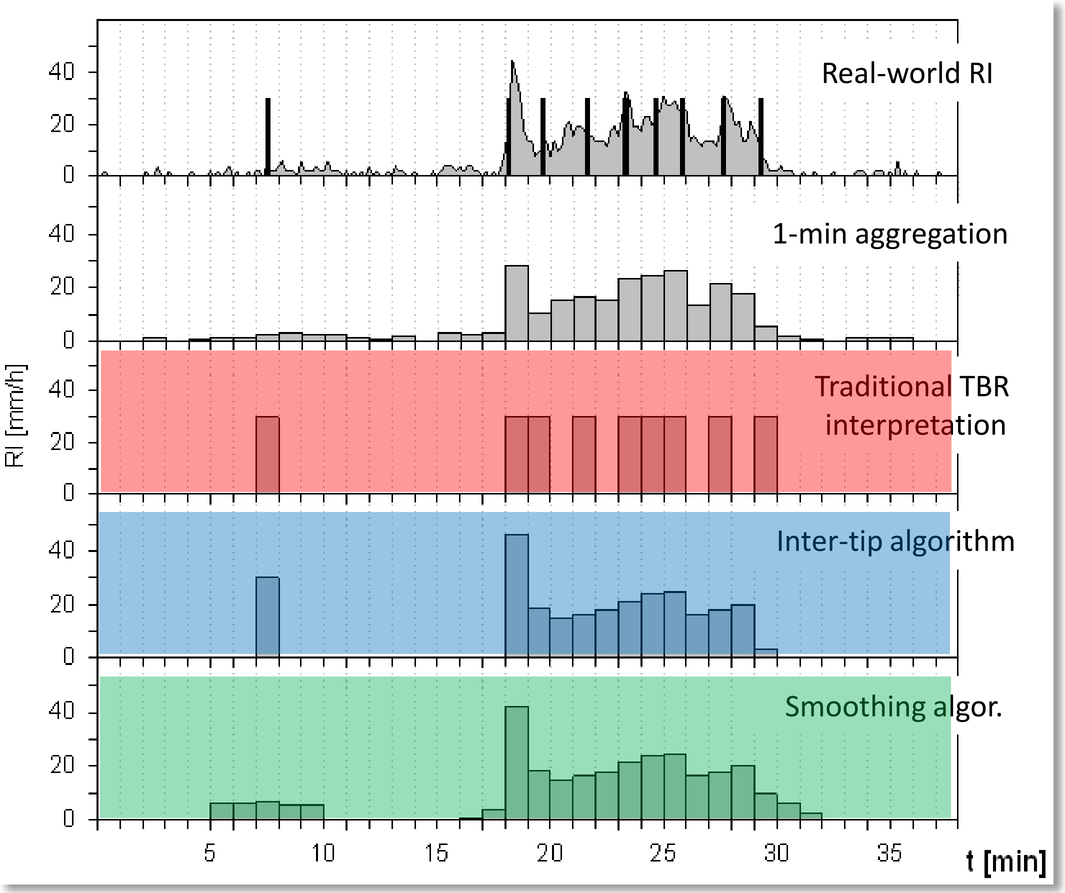
Development of algorithms aimed at the improvement of the rainfall intensity sampling performed by tipping-buckets type gayges. The investigations was carried out by means of numerical simulations of real-world events measured by the Hong Kong Observatory drop counter located at the HK International Airport.

The TBR sensitivity were simulated in order to isolate the effect of sampling limitations from other typical uncertainties factors (mechanical errors, wetting looses, etc.):

h_n=0.5 mm

The tested algorithms consist of:

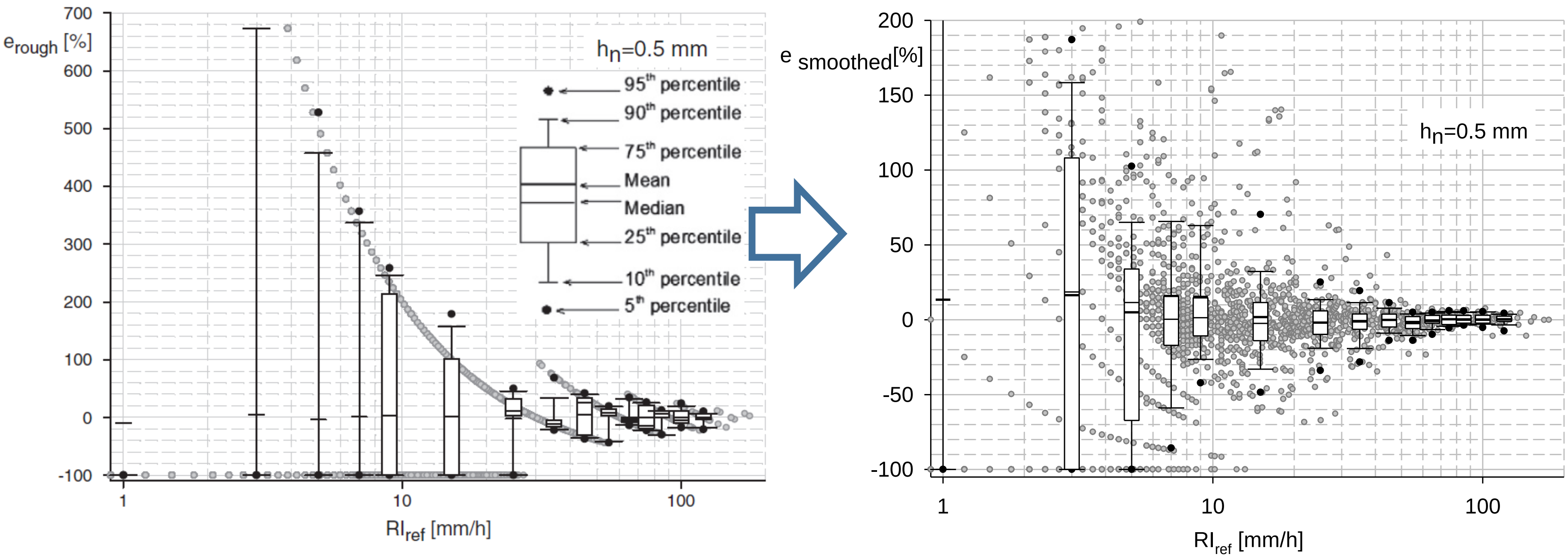
- a traditional interpretation of the volumetric sampling.
- an improved algorithm based on the inter-tip times.
- statistical disaggregation of version n. 2 (smoothing algorithm).



Colli, M., Lanza, L.G., Chan, P.W., (2013)

THE SAMPLING ISSUE

Box plots of the one-minute RI measurements errors obtained by an ideal TBR with sensitivity h_n=0.5 mm.

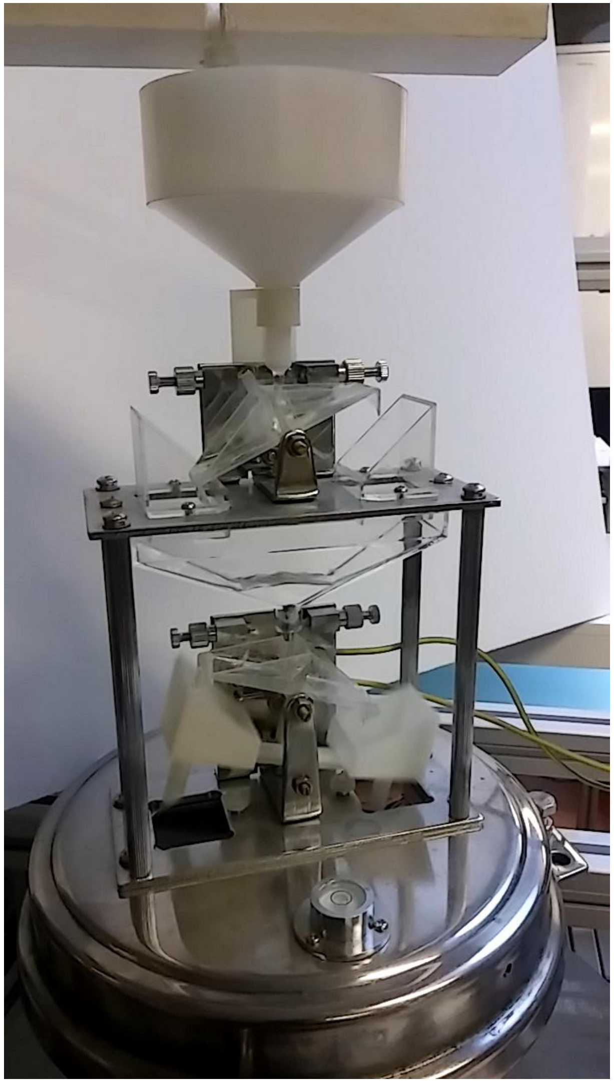


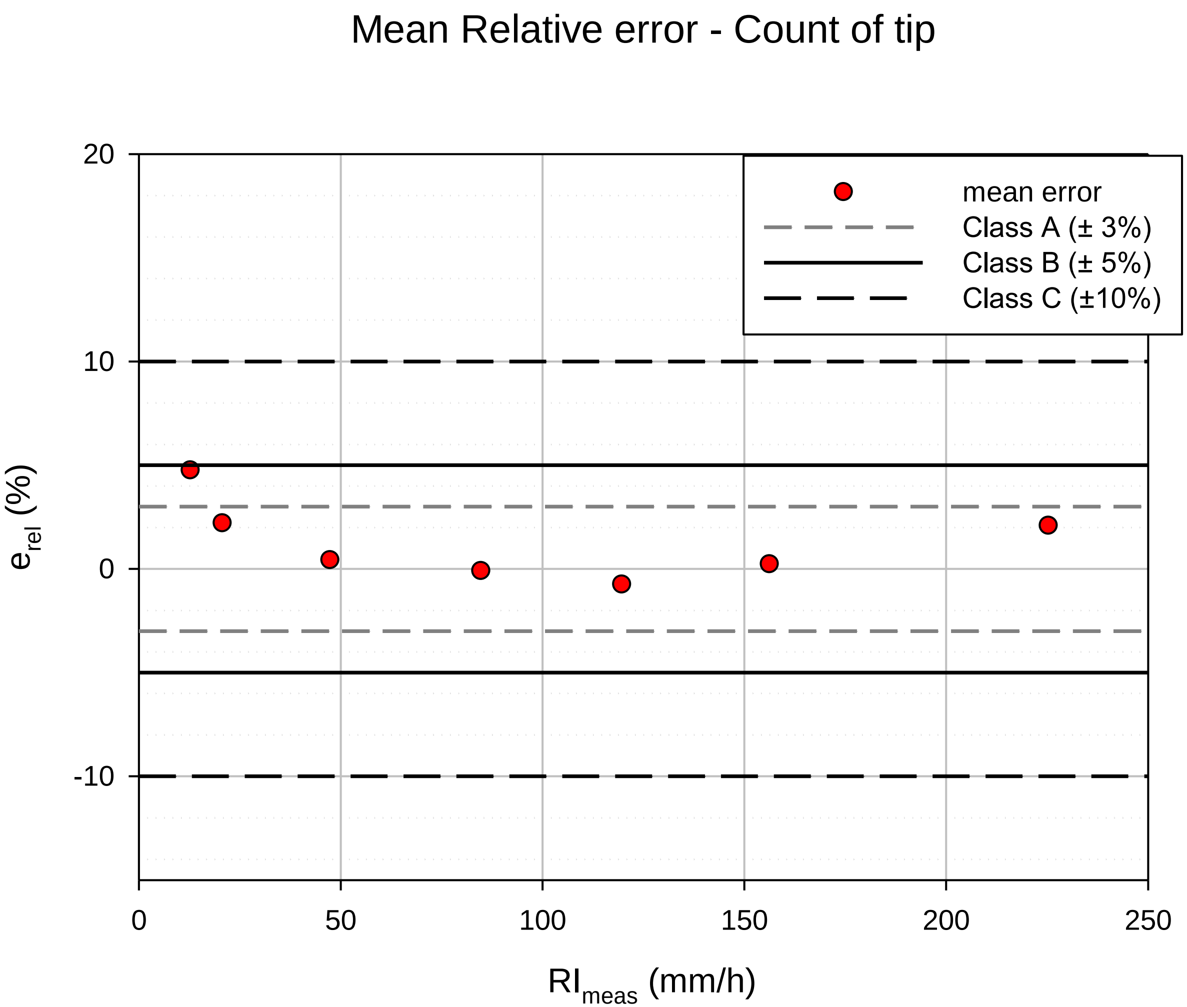
e_{rough}: errors using a traditional interpretation algorithm

$e_{smoothed}$: errors using the improved algorithm

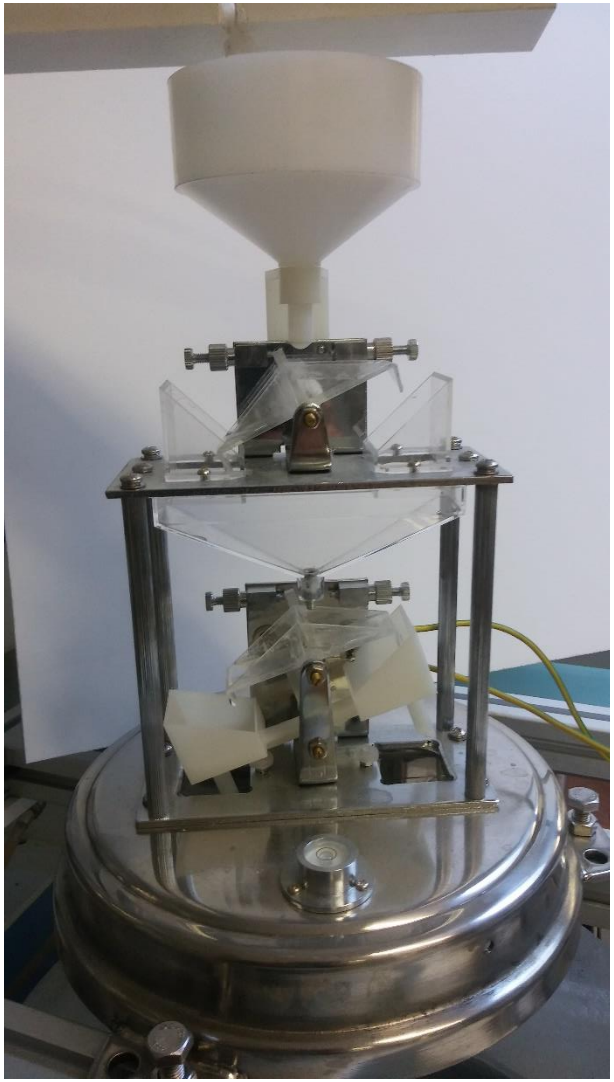
Colli, M., Lanza, L.G., Chan, P.W., (2013)

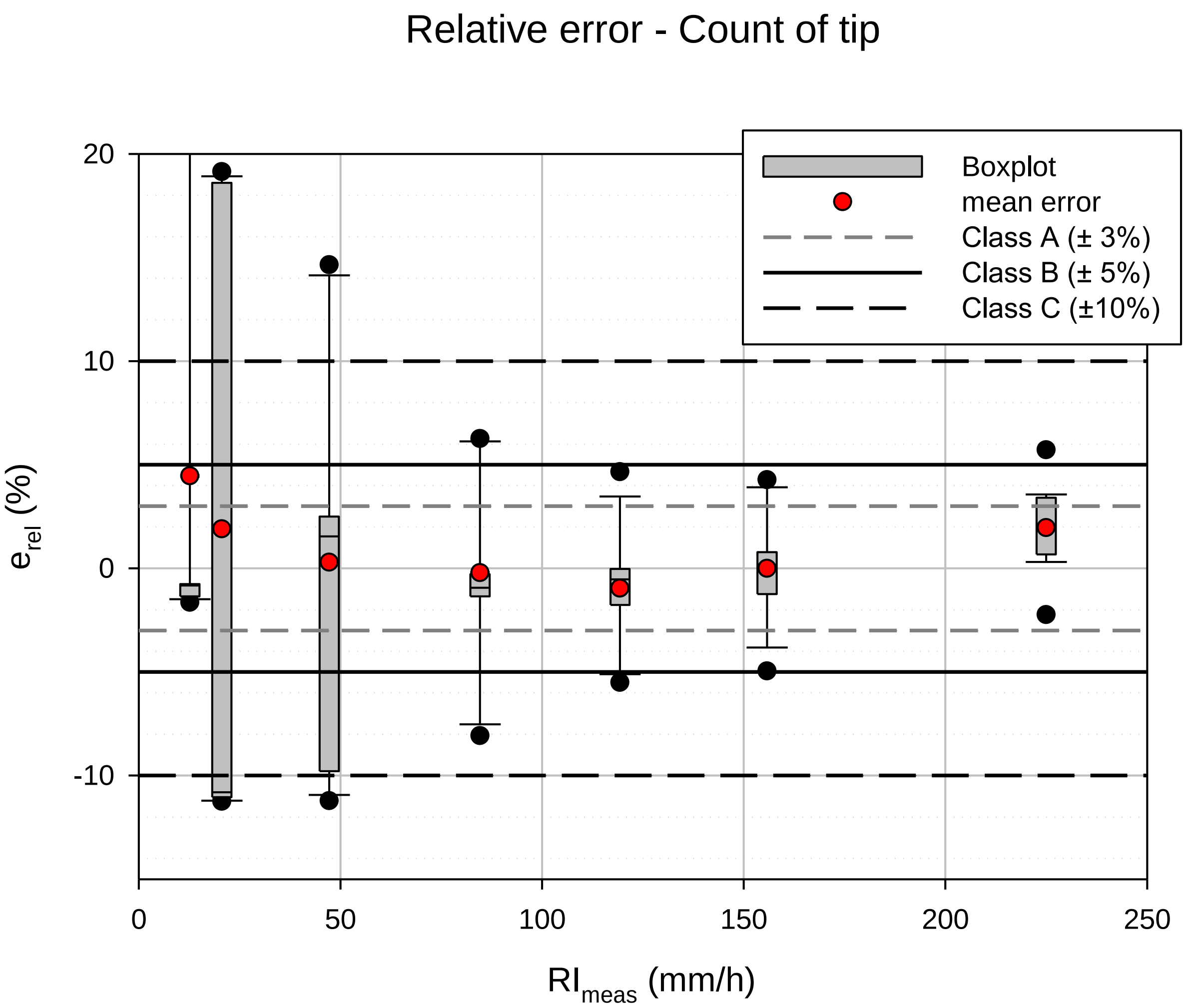
THE DOUBLE LAYER TBRG - Shangai SL3



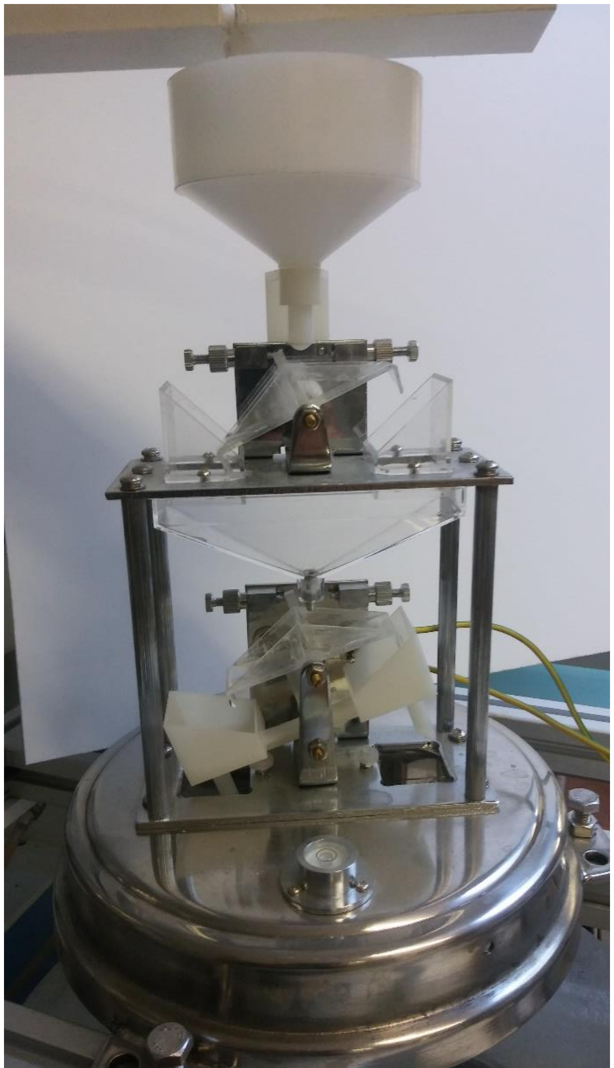


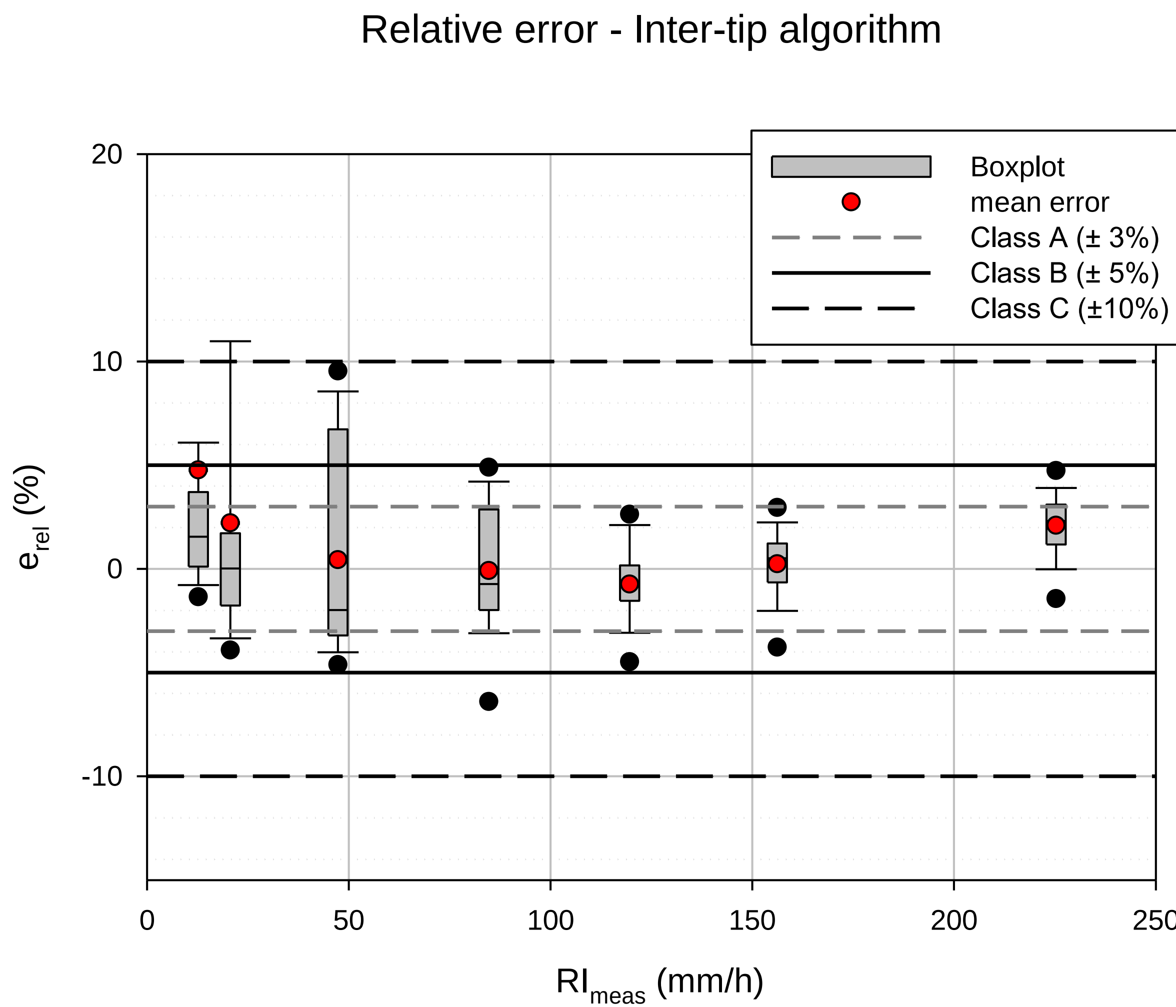
THE DOUBLE LAYER TBRG - Shangai SL3





THE DOUBLE LAYER TBRG - Shangai SL3



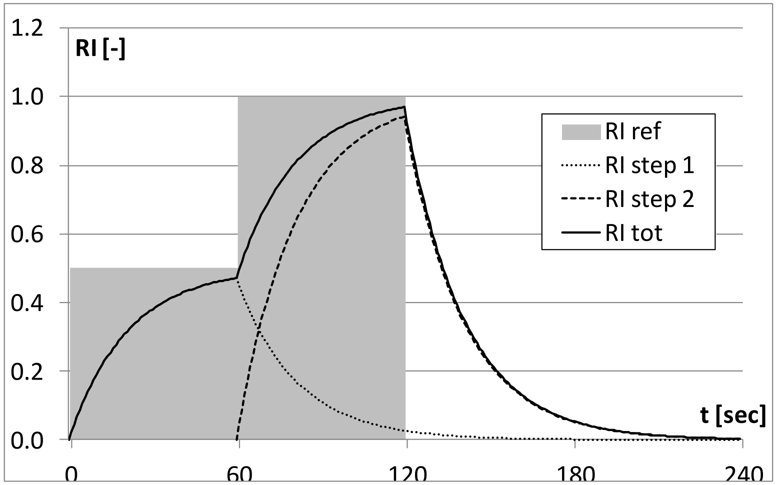


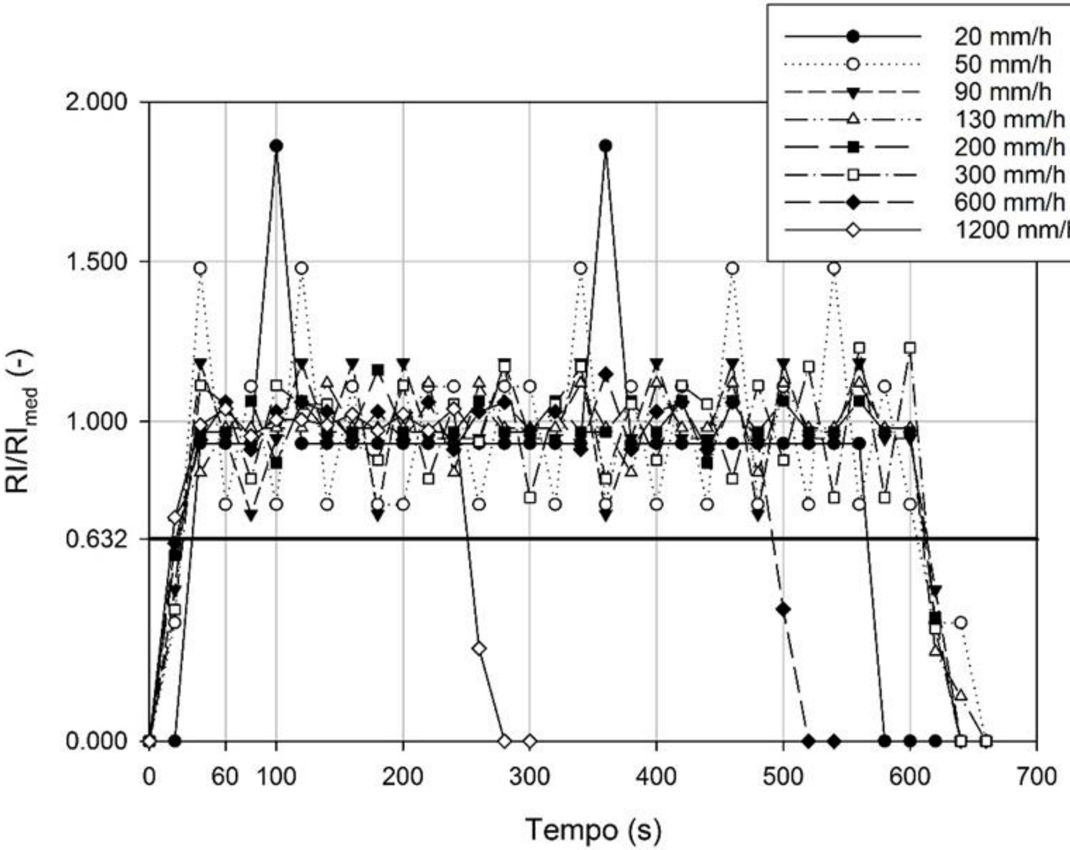
➢ Weighing Gauges

University of Genova
WMO/CIMO LC-PrIn

Correction methodology for WGs based on the similarity with a first order dynamical system.
The estimation of WG dynamic behavior has been performed by realizing single, double and multiple steps flow rates with the laboratory RI generator.

$$y(\tau) = 1 - e^{-\frac{t}{\tau}}$$





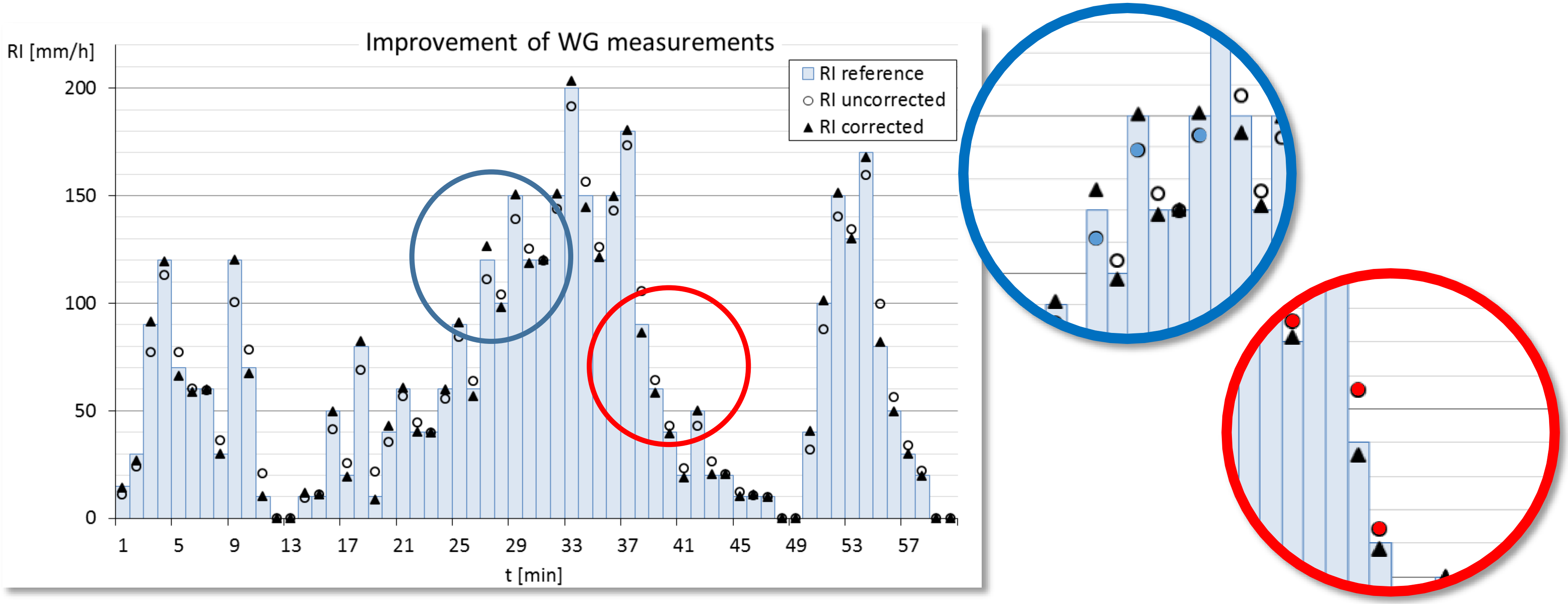
$$h_{I\,min} = dt - \tau\left(1 - e^{\left(-dt/\tau\right)}\right)$$

$$h_{II\,min} = \left(dt - \tau\left(1 - e^{\left(-dt/\tau\right)}\right)\right)(1+\alpha) + \\ + \alpha\,\tau\left(1 - e^{\left(-dt/\tau\right)}\right)^2$$

➢ Weighing Gauges

University of Genova
WMO/CIMO LC-PrIn

Improved estimation of Rainfall Intensity employing the correction methodology:



Colli, M., Lanza, L.G., La Barbera, P., 2013

➢ Drop Counter Rain Gauges

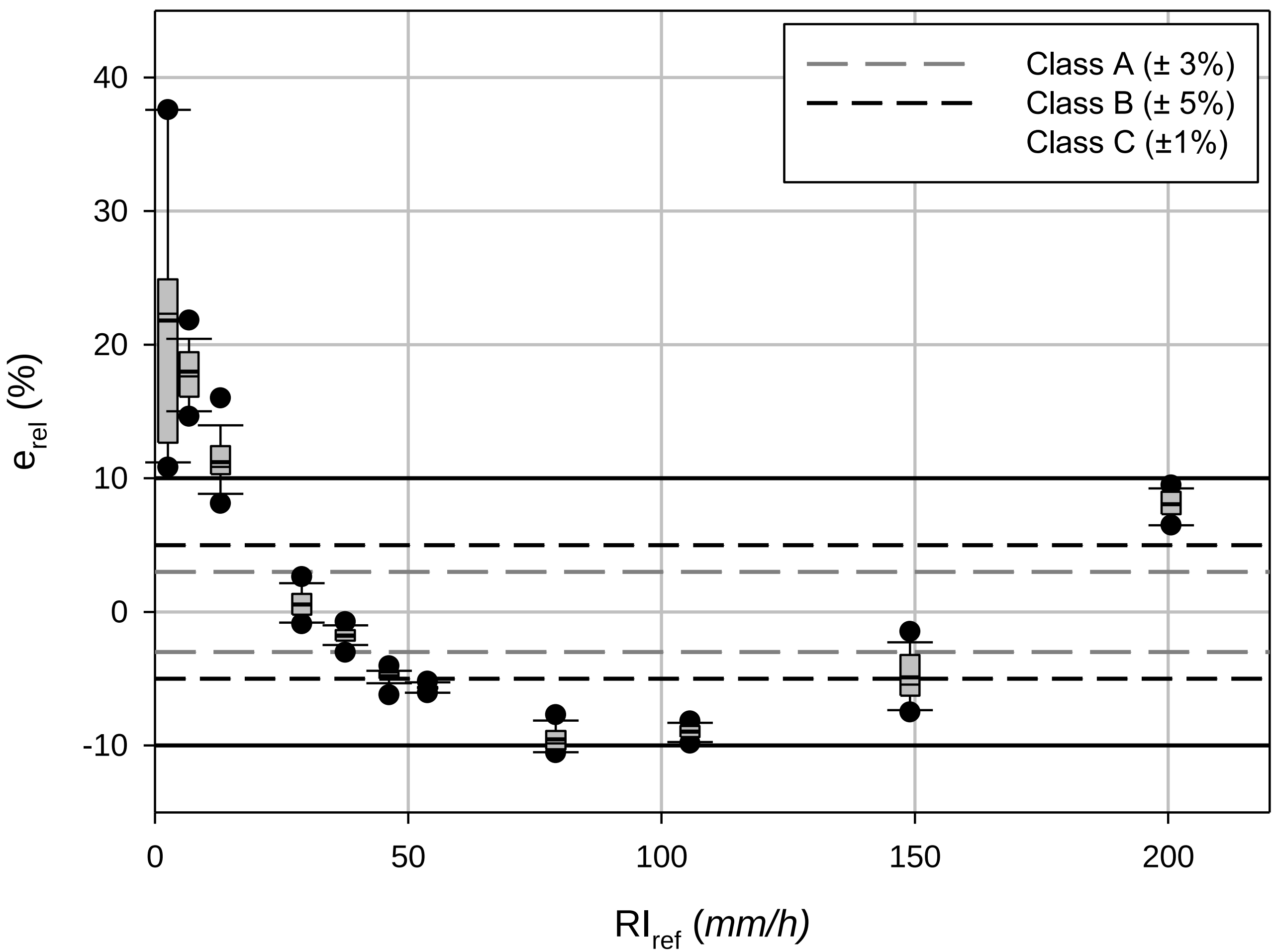
Measuring Principle:

- It is a catching type Rain gauge.
  The funnel collect the rain towards a calibrated nozzle which start to drip.

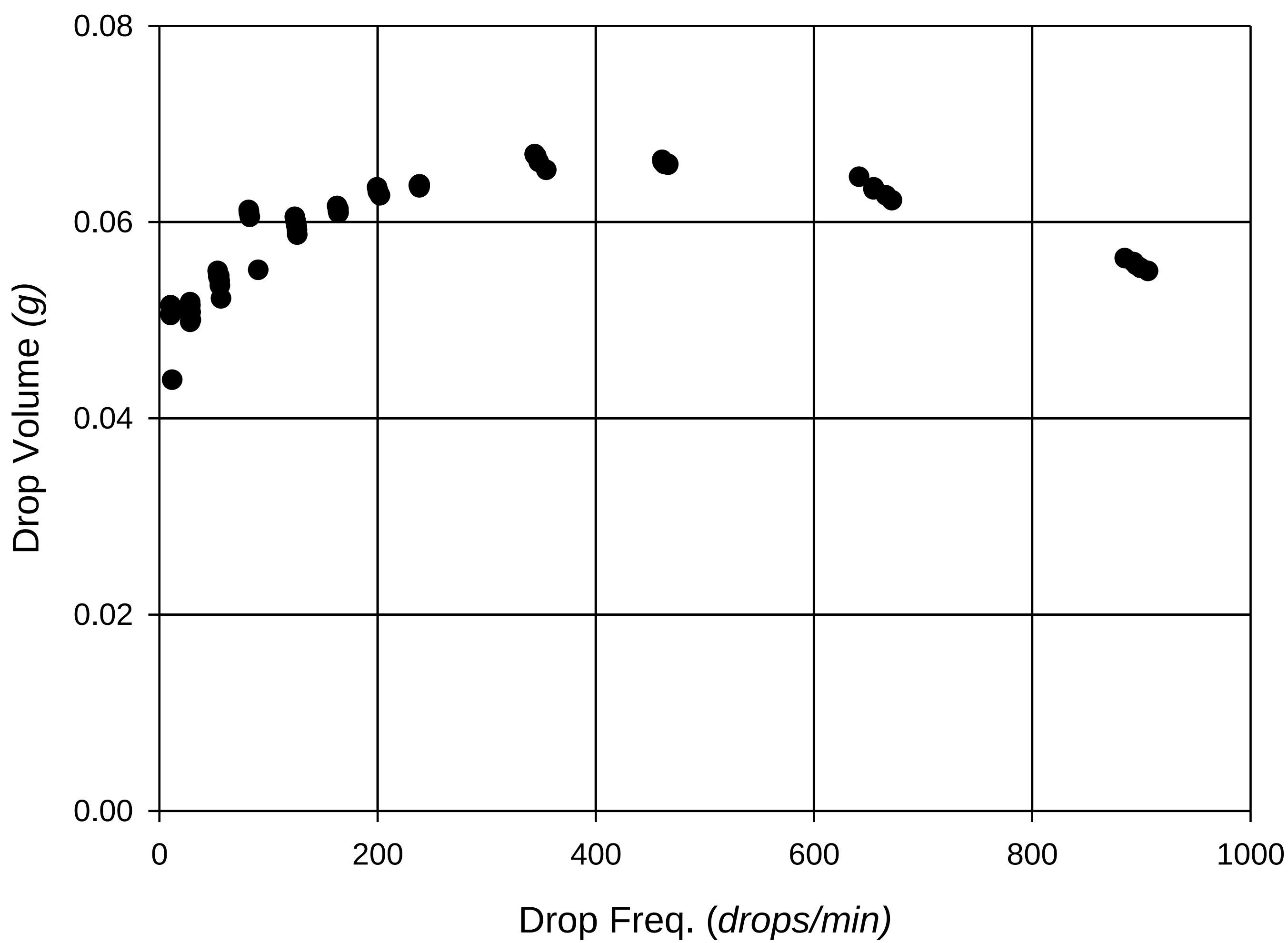
- An optical sensor, placed under the nozzle, detect the drop passage and calculate the drop frequency. The droplet frequency is related to the rainfall intensity.

- The total volume measured by the sensor is calculated assuming a constant volume of the droplets.

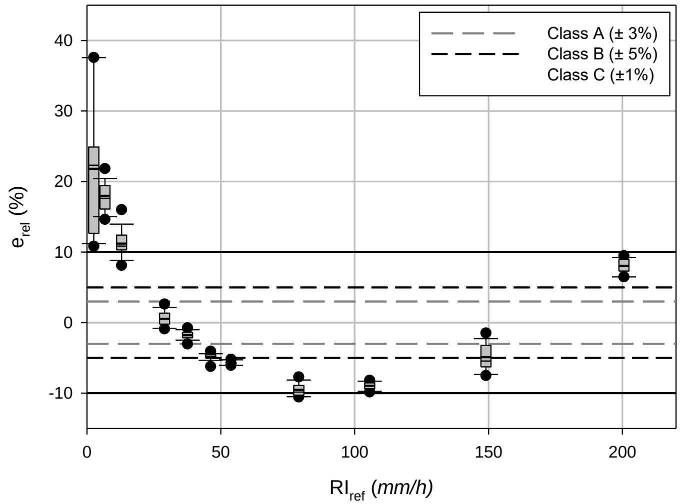
Performance of Drop Counting Rain Gauge under Dynamic Calibration using a constant drop volume



The tests show that the volume of the droplets varies as the drop frequency changes:

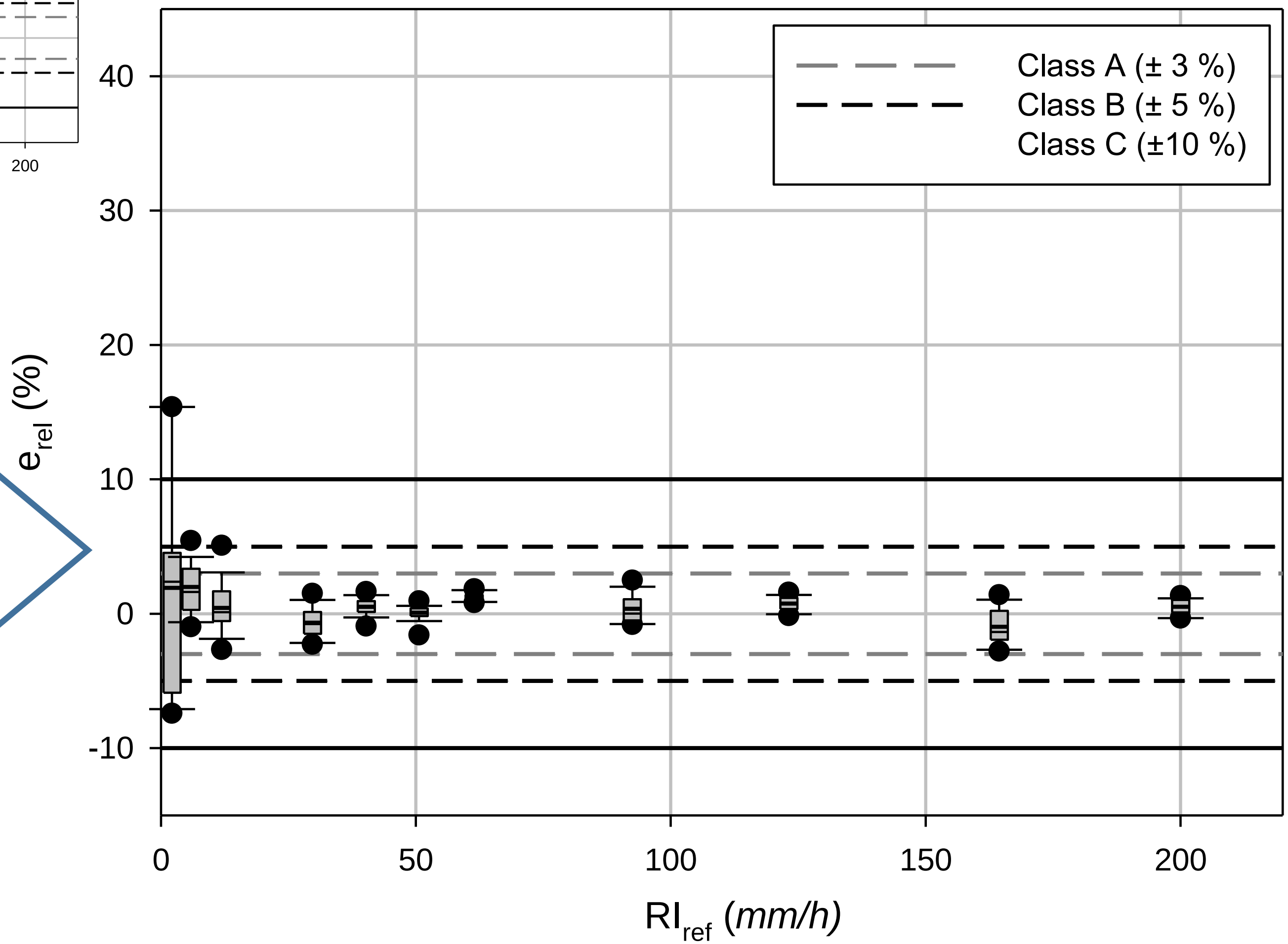


➢ Drop Counter Rain Gauges



$$V_{drop} = f(DF)$$

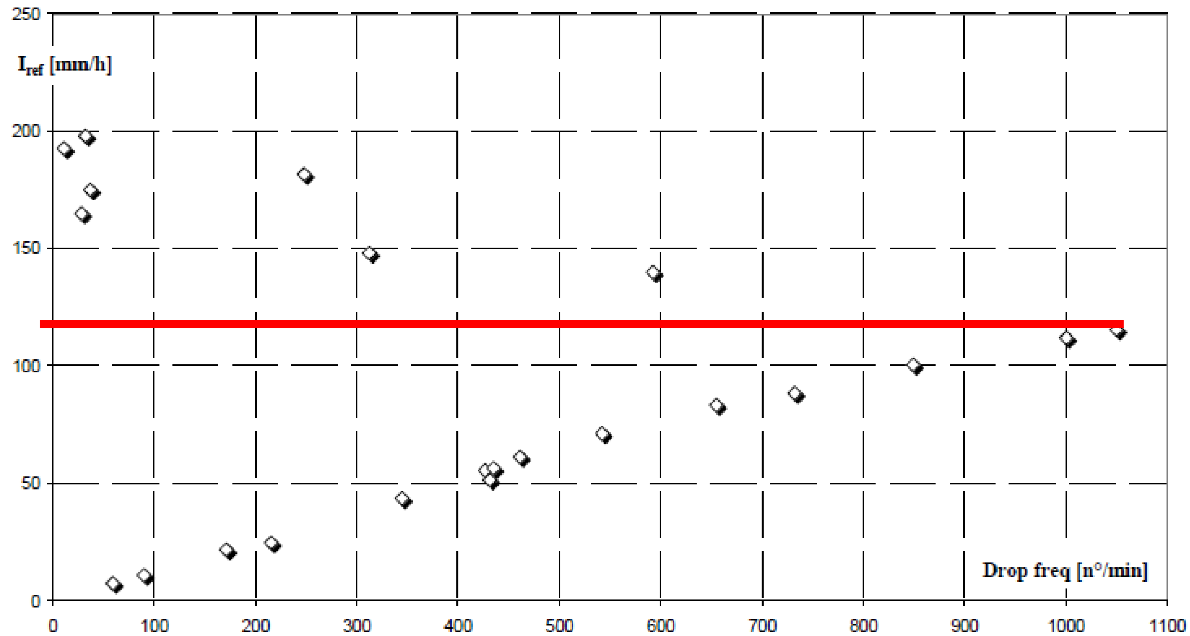
Adopting a calibration curve of the drop volume, the instrument performance increase and fulfil the Class A requirements for almost the full operating range.



Drop Counter Rain Gauges

Operational limit:

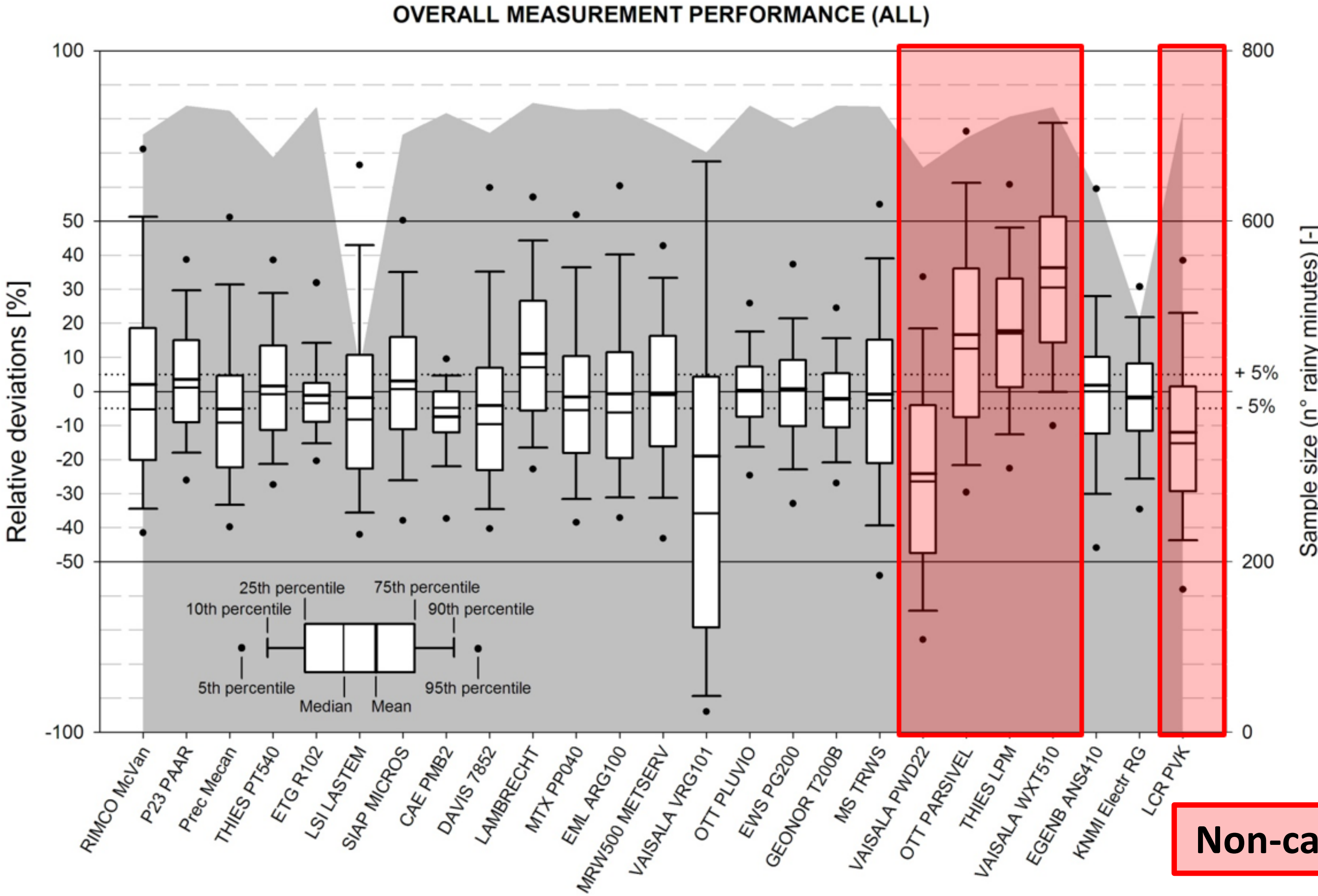
The operational limit of this kind of instrument is given by the RI at which the water flux from the nozzle starts to be continuous or it can not be considered as a regular drop dispensing flux.



Since the instrument measures only frequencies of the droplets, it is not possible to know a-priori the real RI, because it is not possible to know if the limit is exceeded or not.
A co-located rain gauge is required to be able to use this gauge operationally.

➢ Non-Catching type Gauges

Tests on NON-Catching type instruments : disdrometers

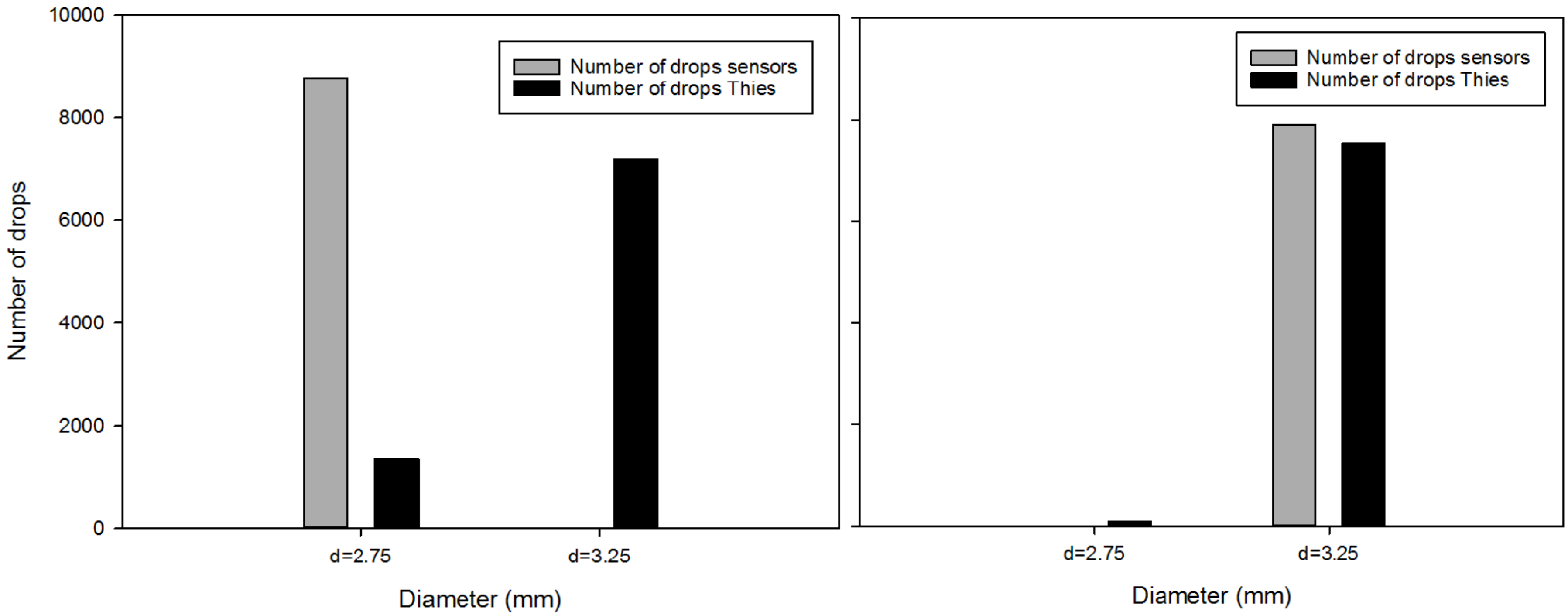


Non-catching type gauges

Non-Catching type Gauges

Tests on NON-Catching type instruments : disdrometers

The results of the tests highlights that the instruments in some cases attribute the drops to the upper class of diameter, inducing a overestimation of rainfall intensity.



References

- BS 7843-3:2012: Acquisition and management of meteorological precipitation data from a gauge network., Standard, British Standards Institution, 2012.
- UNI 11452:2012: Hydrometry - Measurement of rainfall intensity (liquid precipitation) - Metrological requirements and test methods for catching type gauges., Standard, Ente Nazionale Italiano di Unificazione, Milano, IT, 2012.
- WMO: Guide to Meteorological Instruments and Methods of Observation (CIMO)-No. 8, World Meteorological Organization, 8th edn., 2014
- Stagi L. and Lanza, L.G. (2006). Device for the generation of various known and constant liquid flow rates. Patent University of Genoa n. 102006A000868, 7 December 2006.
- Colli, M., Lanza, L.G. and P.W. Chan (2013). Co-located tipping-bucket and optical drop counter RI measurements and a simulated correction algorithm. *Atmos. Res.*, **119**, 3-12.
- Colli, M., Lanza, L.G. and P. La Barbera (2013). Performance of a weighing rain gauge under laboratory simulated time-varying reference rainfall rates, Atmos. Res., 131, 3-12
- Stagnaro, M., Colli, M., Lanza, L.G. and P.W. Chan (2016). Performance of post-processing algorithms for rainfall intensity measurements of tipping-bucket rain gauges. J. Atmos. Meas. Techn., **9**, 5699–5706.

for further information:

http://www.precipitation-intensity.it

mattia.stagnaro@unige.it
luca.lanza@unige.it