The WMO Field Intercomparison of RI Gauges:

Methods, tools and possible drawbacks within the Data Analysis Task

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WORLD METEOROLOGICAL ORGANIZATION

Joint Expert Team on Surface Based Instrument Intercomparisons and Calibration Methods (ET) and
Intrnational Organizing Committee on Surface Based Instrument Intercomparisons (IOC)

Meeting on the WMO Field Intercomparison of Rainfall Intensity Gauges

The WMO Field Intercomparison of RI Gauges:

Dealing with "brand new" issues in the assessment of RI measurement accuracy and reliability

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The WMO Field Intercomparison of RI Gauges:

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The field intercomparison goals are twofold:

1) To learn about the "good" measurement qualities of the involved instruments…

2) To learn as much as possible about their issues/drawbacks and faults

by an accuracy evaluation – or more in general a performance analysis - of different typologies of Rain Gauges, as installed in field and compared with one (or more?) reference RIGs

We have than to provide specific statistical/probabilistic tools for these two "strictly connected" objectives, always taking in account the complex nature of the observed phenomenon…

The WMO Field Intercomparison of RI Gauges:

Dealing with "brand new" issues in the assesment of RI measurement accuracy and reliability

Different drawbacks could be connected with different phases of data analysis

Data Acquisition, Pre-processing and validation: basically aimed at "producing" a reliable reference RI from the 4 reference gauges and acquiring -in the most effective way- comparable RI data from the 28 (?) gauges under test...

Data Analysis and Performance evaluation for the the involved instruments: The goal is evaluating performance and accuracy of the 28 (?) gauges under test...

Issues connected with the positioning of gauges within the test field: particular installation geometries could produce spurious correlation between the instruments...?

The basic issue of assessing the reference RI, starting from the 4 reference gauges data: Should be the reference RI a summary value or a function of boundary conditions (RI intensity and ancillary data values), or both? And more, should it be unique?

Validation issues...

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How could we define (relative) error? Contrary to Laboratory Intercomparison the relative error definition "in field" is not trivial: Could be the relative error a combination of residuals probabilistic characteristics (distribution parameters and type) and statistical summaries (mean, mode, median, standard error)?

Performance is an univocal value or a function of more parameters? How can we obtain an accuracy as a function of RI value, ancillary measurements values, readiness and so on... (unique performance index)?

The WMO Field Intercomparison of RI Gauges:

Dealing with "brand new" issues in the assesment of RI measurement accuracy and reliability

Data Acquisition, Pre-processing and validation:
basically aimed at "producing" a reliable reference RI from the 4 reference gauges and acquiring -in the most effective way- comparable RI data from the 29 gauges under test...

For both these phases of data processing and analysis of results, it could be important to foreseen a "running in" period (of ? Months), devoted to the test of different elaboration procedures

Data Analysis and Performance evaluation for the the involved instruments:
The goal is evaluating performance and accuracy of the 29 gauges under test...

Field versus Laboratory Intercomparison framework

Concurrent measurements versus controlled laboratory testing

Even though a signal component might carry a lot of information, it is often considered a noise if we cannot make sense out of it. In a crowd of people speaking a language we do not understand, surrounding conversations are generally perceived as noise background. However our attention will be attracted by any remote conversation in a language we know. In this case, what is important is not the information content but whether this information is in a coherent format with respect to our system of interpretation. **Mallat e Zhang (1993)**

In this context, the main issue is represented from our necessity of distinguish between instrumental errors, noise and test field climatologic /"orographic" patterns.

The rainfall process in space & time
Coping with complexity and intermittency at the whole scales

Rainfall Intensity at a generic time t and in a fixed point of the space given from the vector $\mathbf{u} \equiv (x, y, z)$ is usually represented as a stochastic process $\{X(\mathbf{u}, t)\}$ from which can be derived the following son processes:

Mean Rainfall Intensity for a given time window (aggregation) T:

$$\{X_T(\mathbf{u}, \mathbf{t})\} \Rightarrow X_T(\mathbf{u}, t) = \frac{1}{T}\int_{t-T/2}^{t+T/2} X(\mathbf{u}, \tau)\ d\tau$$

The integral process of Rainfall Depths aggregated on the same time window T:

$$\{I_T(\mathbf{u}, \mathbf{t})\} \Rightarrow I_T(\mathbf{u}, t) = \int_{t-T/2}^{t+T/2} X(\mathbf{u}, \tau)\ d\tau$$

The rainfall process in space & time

Coping with complexity and intermittency at the whole scales

Both the processes depend on the aggregation scale in time and the relation among them cam be described as:

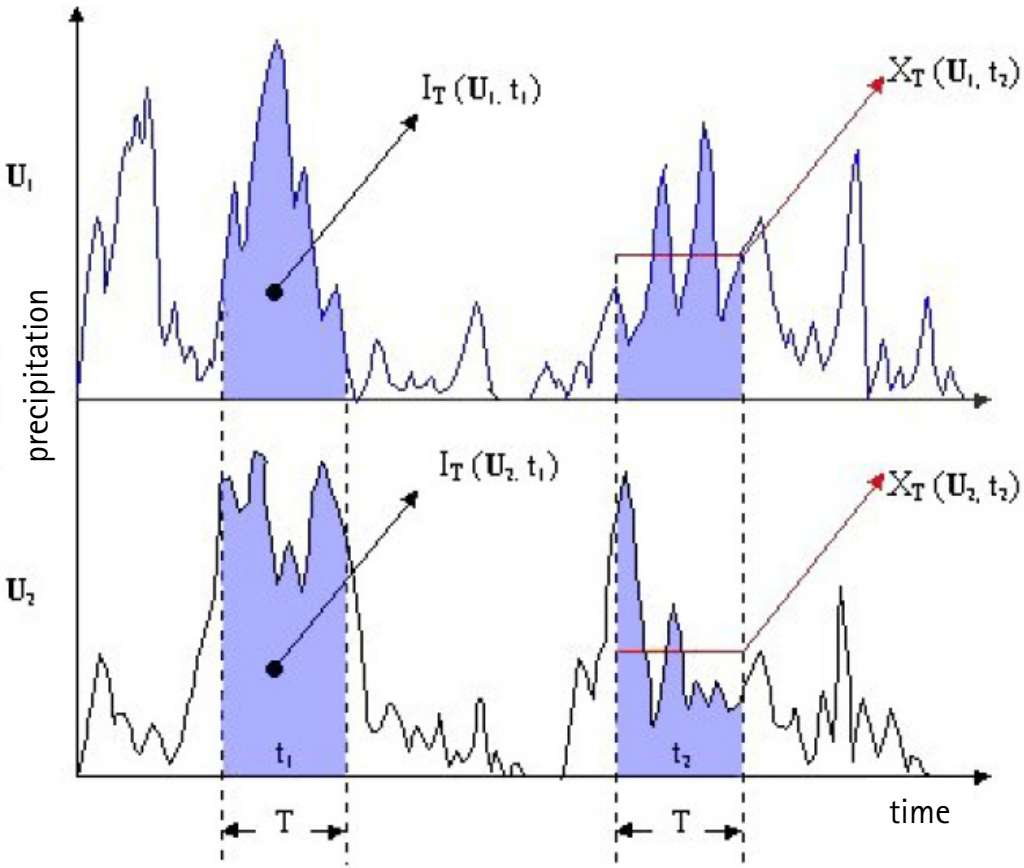
$$X_T(\mathbf{u},t) = \frac{1}{T} I_T(\mathbf{u},t)$$

Mean Rainfall Intensity for a given time window (aggregation) T:

$$\{X_T(\mathbf{u},\mathbf{t})\}$$

The integral process of Rainfall Depths aggregated on the same time window T:

$$\{I_T(\mathbf{u},\mathbf{t})\}$$



The rainfall process in space & time
Coping with complexity and intermittency at the whole scales

Even if time series produced by the RI gauges within the test field can be treated as a space-time stochastic process (or better the rainfall process measured in that area can be treated as a S-T stochastic process…), we must consider that such a process will be probably:

Not stationary: Moments until second order depends on time (weak stationarity)

Not Homogeneous: the moments of the process depends on the position in space

Not isotropous: the properties of the process change along different directions within the field

Due to the fact that we foreseen different behaviours for different gauges, but also additional correlation patterns connected to the presence of noise and climatic/orographical effects

"In theory, theory and practice are the same. In practice, they are not." (**Albert Einstein**)

The WMO Field Intercomparison of RI Gauges:

Coping with complexity and intermittency at the whole scales: Correlation analysis

The properties of the "measured" testing field can be e.g. investigated by mean of a correlation/covariance analysis and principal components analysis:

Correlation Function

$$\varrho_{I_{\Delta t}}(i,j) \simeq \cdot \frac{\frac{1}{N-\tau}\cdot \sum_{k=1}^{N-\tau}\left[X_k(\mathbf{u}_i)-\bar{X}(\mathbf{u}_i)\right]\cdot\left[X_{k+\tau}(\mathbf{u}_j)-\bar{X}(\mathbf{u}_j)\right]}{\hat{\sigma}_X(\mathbf{u}_i)\cdot\hat{\sigma}_X(\mathbf{u}_j)}$$

Minimizing: $\varrho_{I_{\Delta t}}(i,j)$

Principal components analysis and cluster analysis

The WMO Field Intercomparison of RI Gauges:

Coping with complexity and intermittency at the whole scales: Correlation analysis

THE BASIC LIMIT OF THESE TOOLS IS THAT THEY ONLY CONSIDER THE LINEAR CORRELATION COMPONENT, NEGLECTING NON-LINEAR CONNECTION

The quantity:

$$I(X,Y) = \sum_{ij} p_{ij} \log\left(\frac{p_{ij}}{p_{i.}\, p_{.j}}\right)$$

Representing the uncertainty on the state of X tied to knowing or knowing not Y is called Mutual information.

Minimizing:

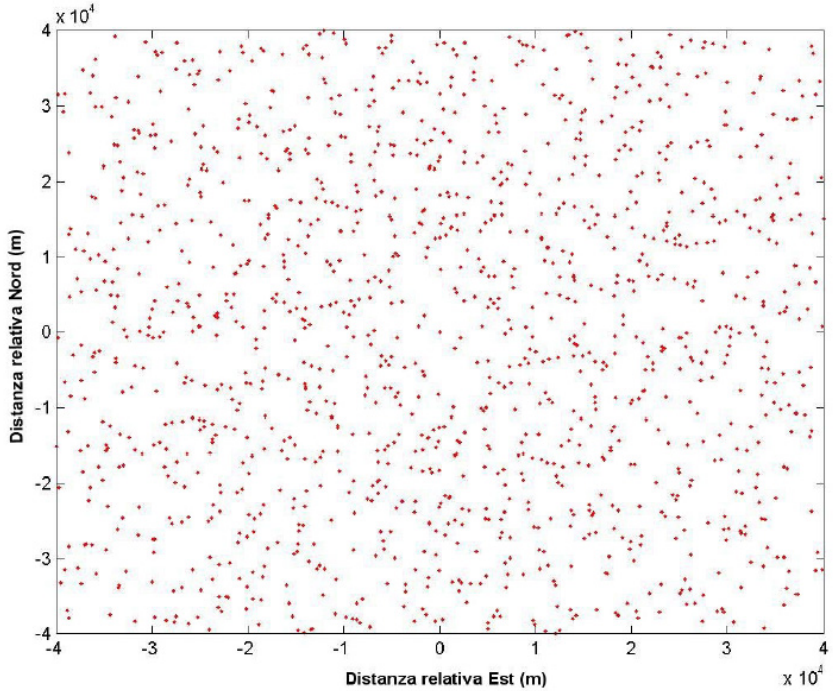
$$\sum_{ij} p_{ij} \log\left(\frac{p_{ij}}{p_{i.}\, p_{.j}}\right)$$

Principal components analysis in a space with non-linear correlation structure

The WMO Field Intercomparison of RI Gauges:

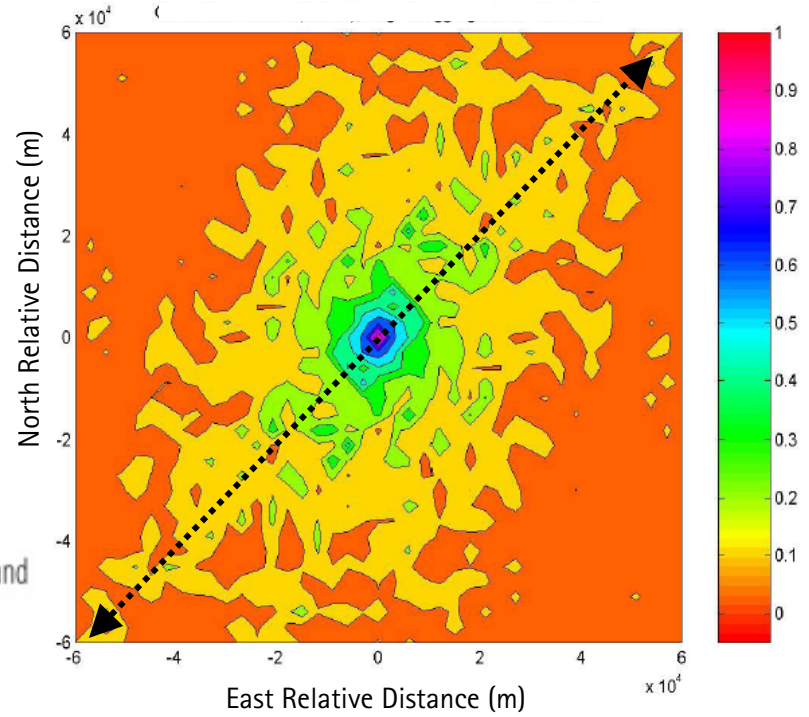
Coping with complexity and intermittency at the whole scales: Correlation analysis

An example of correlation patterns for TBR stations of Piemonte Region Meteorological Service



Patterns along a specific direction: correlation analysis

Summer cross-correlation (lag=0, T=10 minutes)

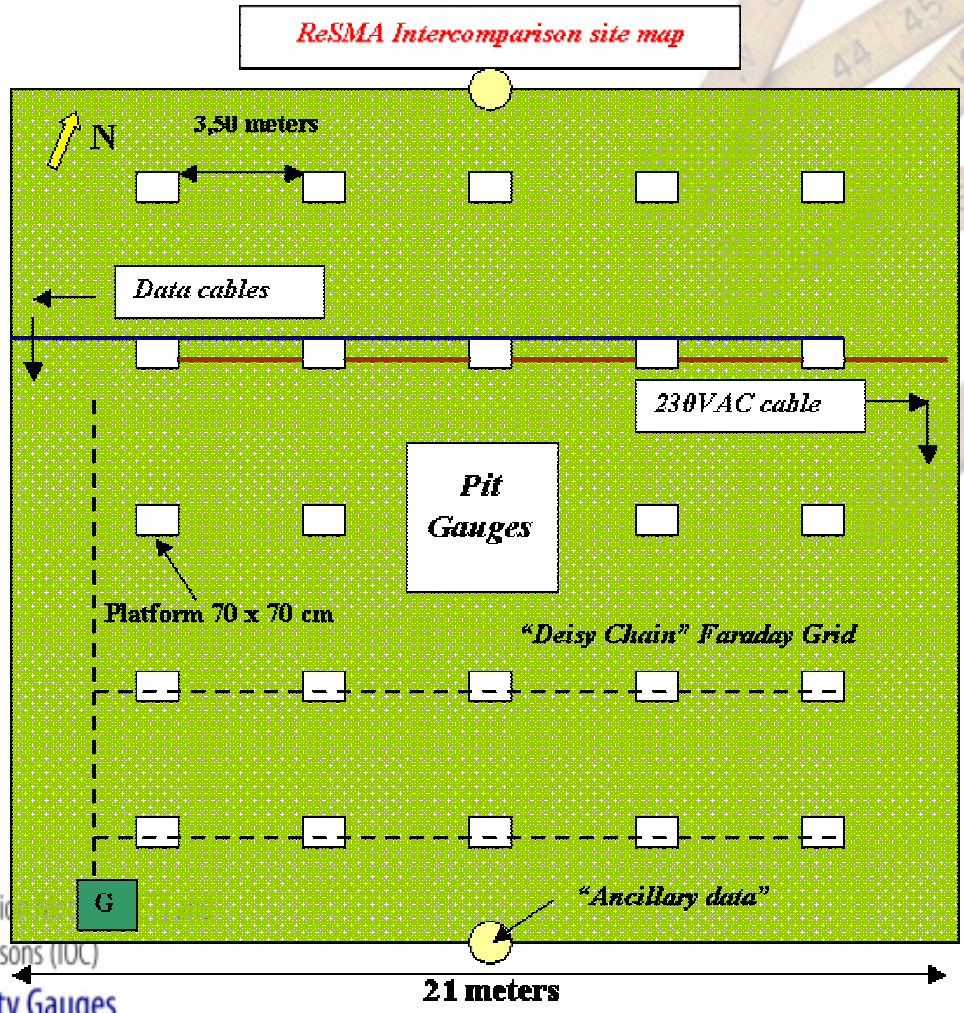


Positioning of gauges within the test field: Installation geometries and spurious correlation between the instruments

Cluster Patterns: principal components analysis

The RI gauges installation must absolutely avoid spurious correlation effects due to the instruments positioning

It could be very important to perform different correlation (linear and not linear) analyses among data during the "running in" period, in order to learn as much as possible about the correlation structure of the testing field and try to filter spurious correlation effects



Field versus Laboratory Intercomparison framework

The problem of assessing a reference RI

Within the Field campaign a main issue is represented from the **assessment of reference RI**, starting from the **4 reference gauges** data...

Basic questions are:

1) Must be the Reference RI unique?
2) And if we need a unique reference intensity, which is the statistic summary more suitable for representing it (mean, median, mode....)?
3) Can the Reference RI be defined as a function of other field parameters ?

The problem of estimating the reference RI accuracy

A further problem is given from the assessment of Reference RI...
Could it be defined in term of a "a-posteriori" parameter such as standard error?
In general or "event by event"?

Field versus Laboratory Intercomparison framework

The problem of assessing a reference RI: possible solutions

Possible forms for the **assessment of reference RI/RIs** are, among others:

1) Estimation of 4 different Reference RI and residual extraction respect all of them?
2) An average reference for TBRs and one for weighing gauges (...and other types of gauges?)...
3) Reference RI as a function of:

- Laboratory error curves
- Eventual Delay assessment
- Climatic conditions (and then ancillary data)

For example in the form of weights for a weighted mean:

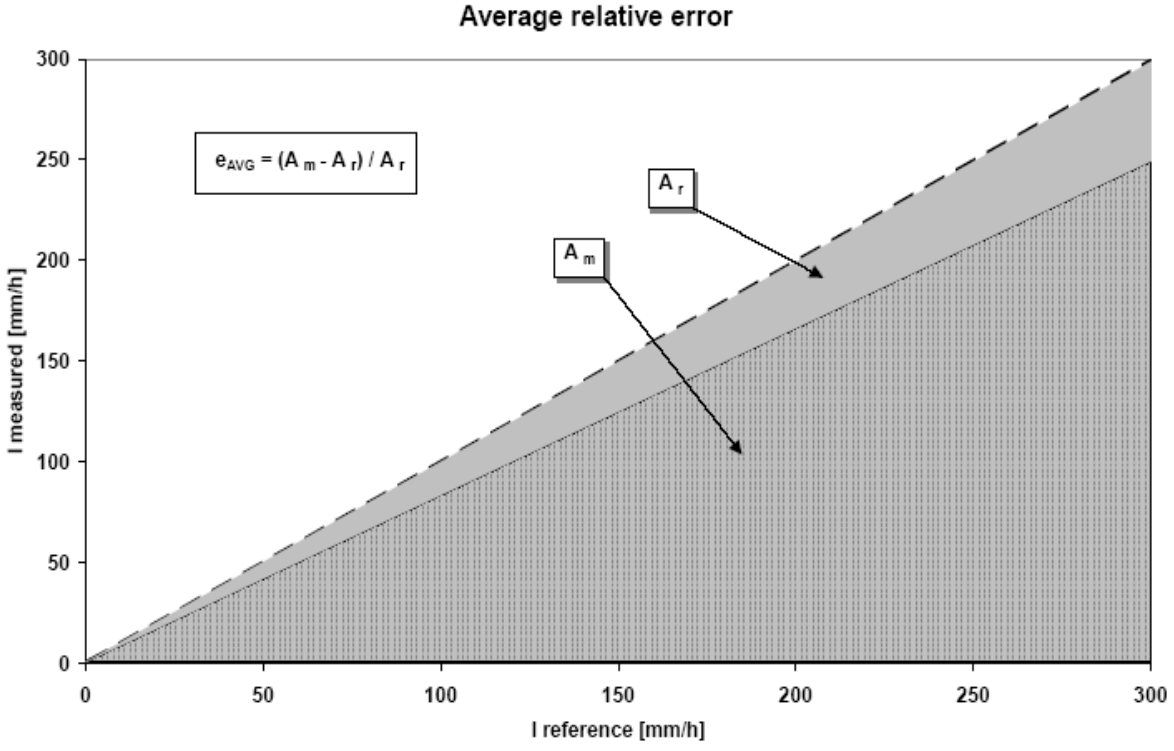
$$W = f(\varepsilon, \Delta\tau, Temp,\ Wind\ speed,\ Wind\ direction...)$$

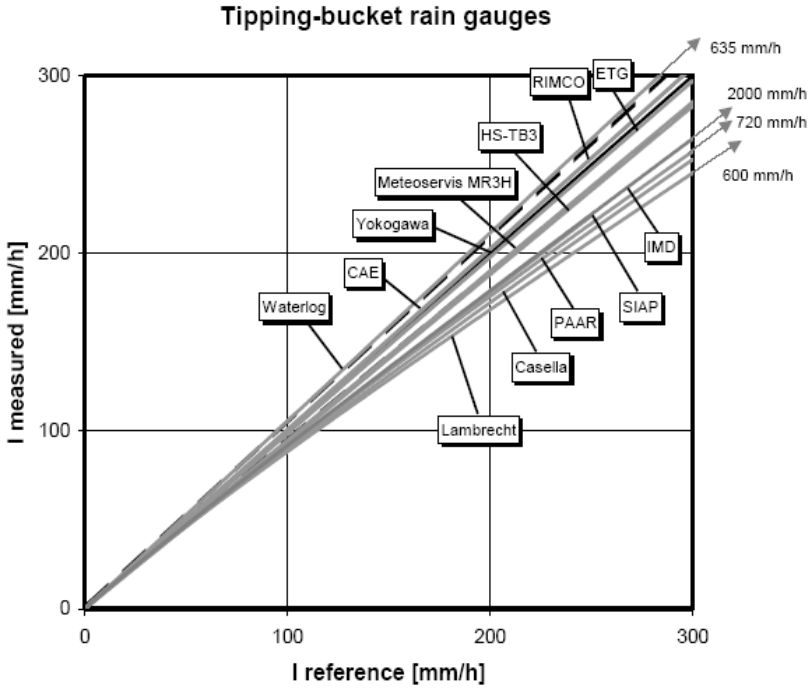
The WMO Field Intercomparison of RI Gauges:

Statistical tools for the definition of Relative Error respect the Reference RI

Contrary to Laboratory Intercomparison the relative error definition "in field" is not trivial: Could be the relative error a combination of:

1. residuals probabilistic characteristics (distribution parameters and type)
2. statistical summaries (mean, mode, median, standard error)?

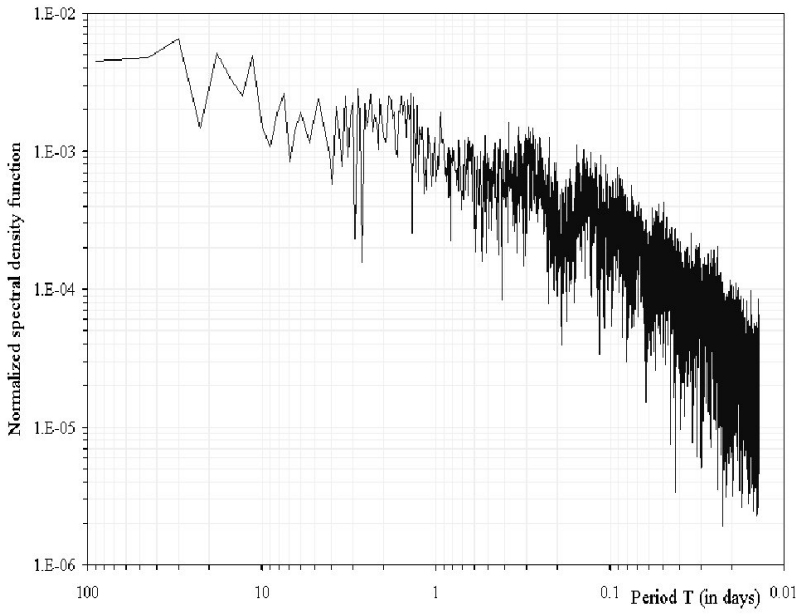


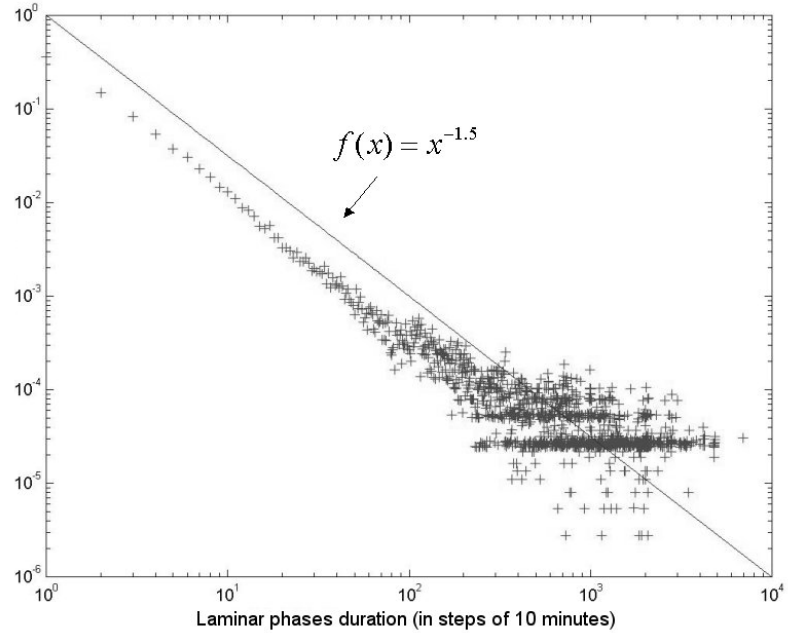


The WMO Field Intercomparison of RI Gauges:

Open questions are also:

1. Are ancillary measurements a tool for characterizing the effects of rainfall process complexity?
2. How can we assess the role of rainfall intermittency in space and time?





3. Performance is an univocal value or a function of more parameters?