# Log-Normality of Indoor Radon Data: Pragmatic Approach

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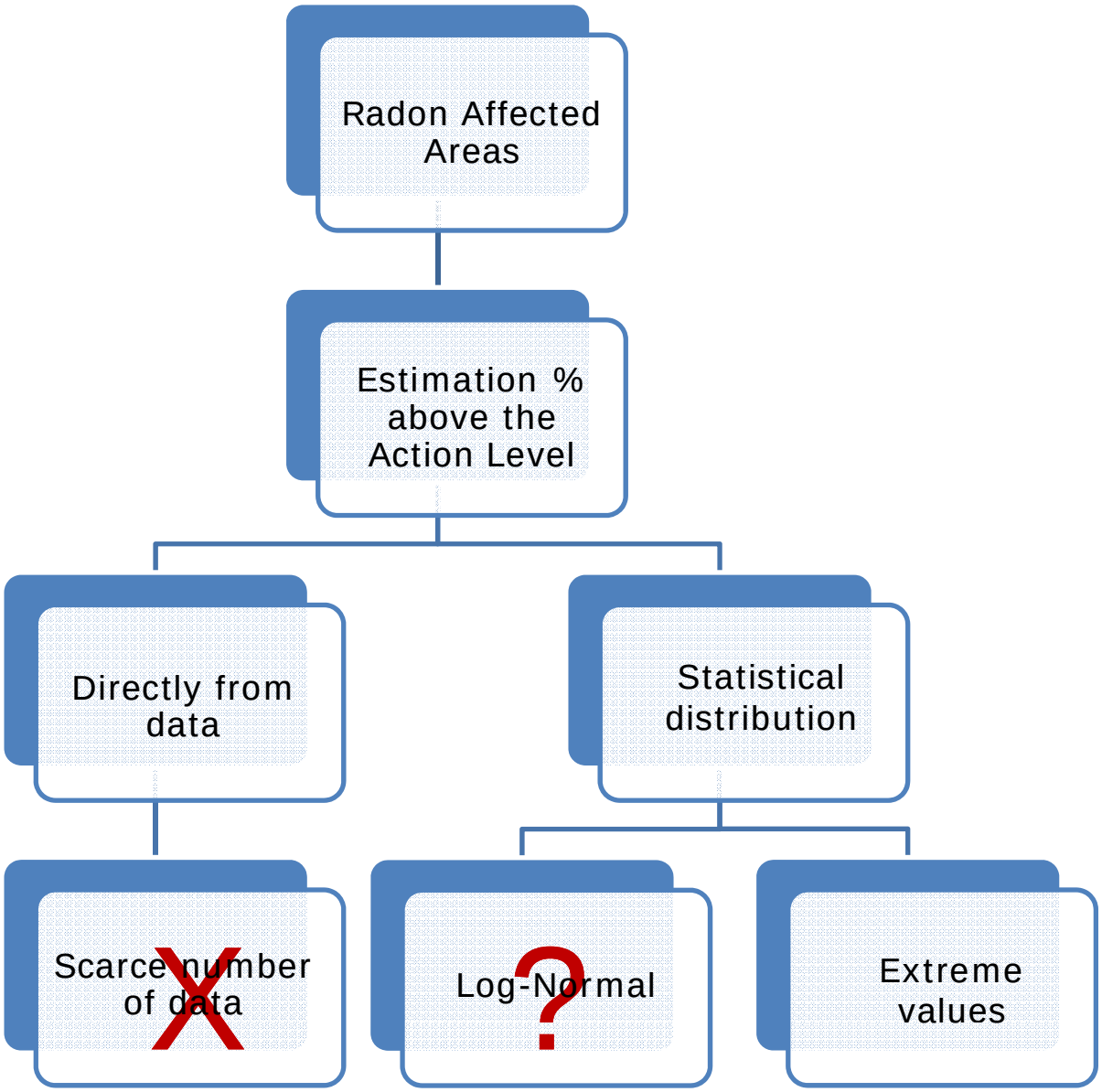

Radon Affected Areas
Estimation % above the Action Level
Directly from data
Statistical distribution
Scarce number of data
X
Log-Normal
?
Extreme values

## Previous Work

- Indoor Data (short+long term) organized in geological units
- Local logarithmic mean calculated considering the nearest 20-30 data
- An average logarithmic standard deviation is calculated, for each unit, after correcting the higher variability of short term data
- Local % of buildings with an indoor radon concentration above the Action level (400 Bq/$m^3$ ) is predicted using a log-normal distribution

## Present Work

Long term Indoor data

1. **Detailed study the Log-Normality of our data and introduction of the Log-Normal High Value Distribution**
2. **Study of the variability of the Logarithmic Standard Deviation within the geological group**

## Indoor radon data

- ~10900
- collected by the Federal Agency for Nuclear Control (FANC)
- using track-etch detectors, exposed 3 months
- on ground floor levels
- from 1995 to 2009

## The database includes:

- geographical coordinates
- radon concentration
- local geological unit (deteminated with the digital geological map)

| | N | LM | LMe | LSD |
|---|---|---|---|---|
| **Revinian(Rv)** | 428 | 4.853 | 4.713 | 1.072 |
| **Salmian(Sm)** | 681 | 4.796 | 4.662 | 0.858 |
| **Gedinnian(G)** | 957 | 4.957 | 4.898 | 0.898 |
| **Siegenian(Cb)** | 3963 | 4.917 | 4.836 | 0.924 |
| **Emsian(Bt)** | 353 | 4.745 | 4.605 | 0.882 |
| **Couvinian(Co)** | 294 | 4.569 | 4.522 | 0.904 |
| **Frasnian(Fr)** | 165 | 4.101 | 4.060 | 0.623 |
| **Famennian(Fa)** | 304 | 4.168 | 4.182 | 0.734 |
| **Trias-Jurassic (Tr-Ju)** | 438 | 4.163 | 4.111 | 0.652 |
| **Eocene (Eo)** | 223 | 3.865 | 3.850 | 0.611 |

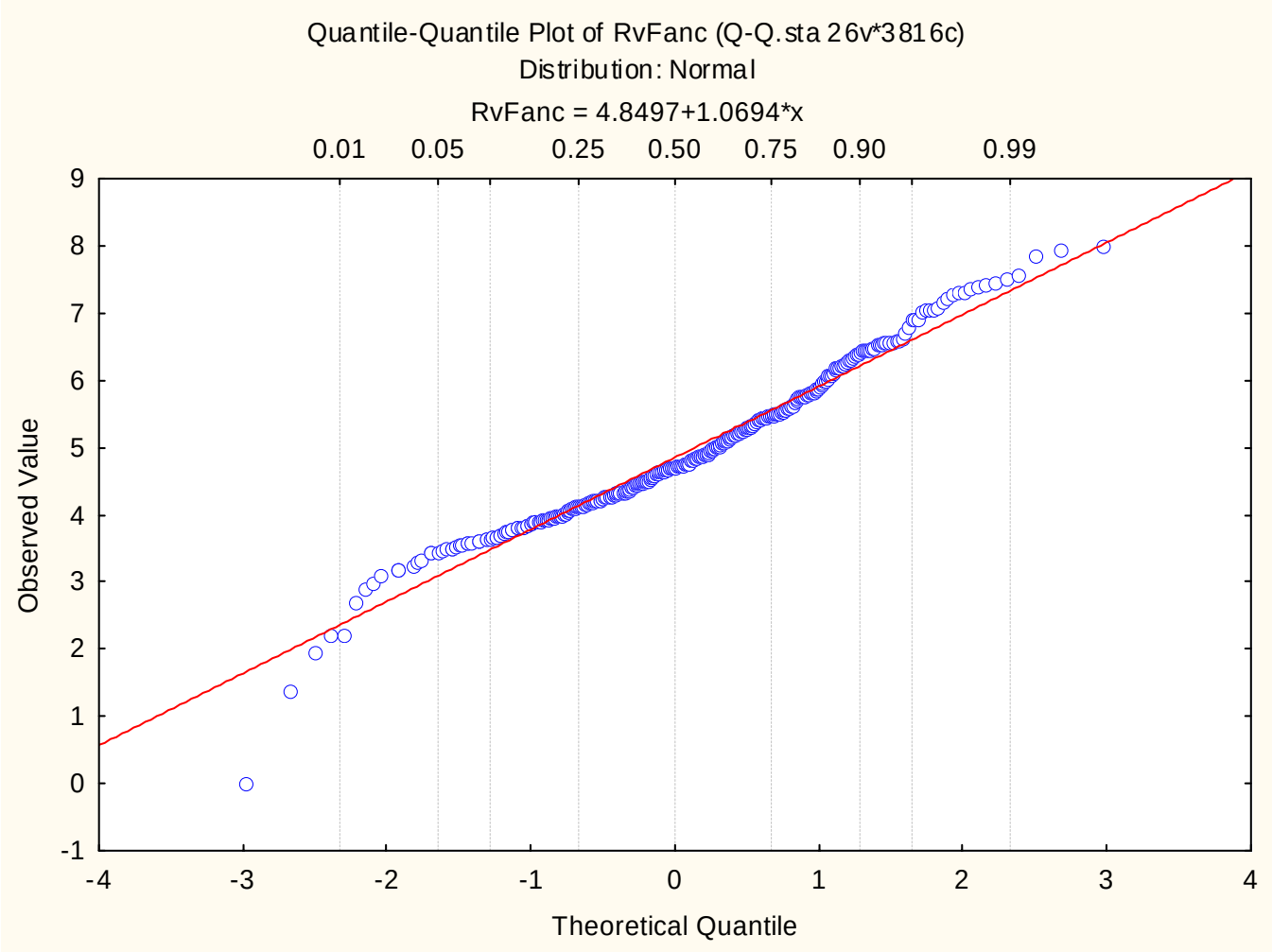
## Hypothesis of log-normality verified using:

- Shapiro-Wilk test
- Method based on the use of skewness and kurtosis ( Tuia and Kanevski 2008)

The lognormal hypothesis is rejected at 0.05 level (when $p<0.05$)

| | N | Skewness | Kurtosis | p-value (S-W test) |
|---|---|---|---|---|
| **Revinian(Rv)** | 428 | 0.293 | 0.852 | 0 |
| **Salmian(Sm)** | 681 | 0.665 | 0.624 | 0 |
| **Gedinnian(G)** | 957 | 0.291 | 1.534 | 0 |
| **Siegenian(Cb)** | 3963 | 0.266 | 0.447 | 0 |
| **Emsian(Bt)** | 353 | 0.686 | 0.732 | 0 |
| **Couvinian(Co)** | 294 | -0.295 | 4.331 | 0 |
| **Frasnian(Fr)** | 165 | 0.644 | 1.961 | 0.001 |
| **Famennian(Fa)** | 304 | -0.174 | 0.792 | 0.001 |
| **Trias-Jurassic (Tr-Ju)** | 438 | 0.956 | 3.501 | 0 |
| **Eocene (Eo)** | 223 | 0.436 | 0.705 | 0.014 |

# Study of Log-Normality



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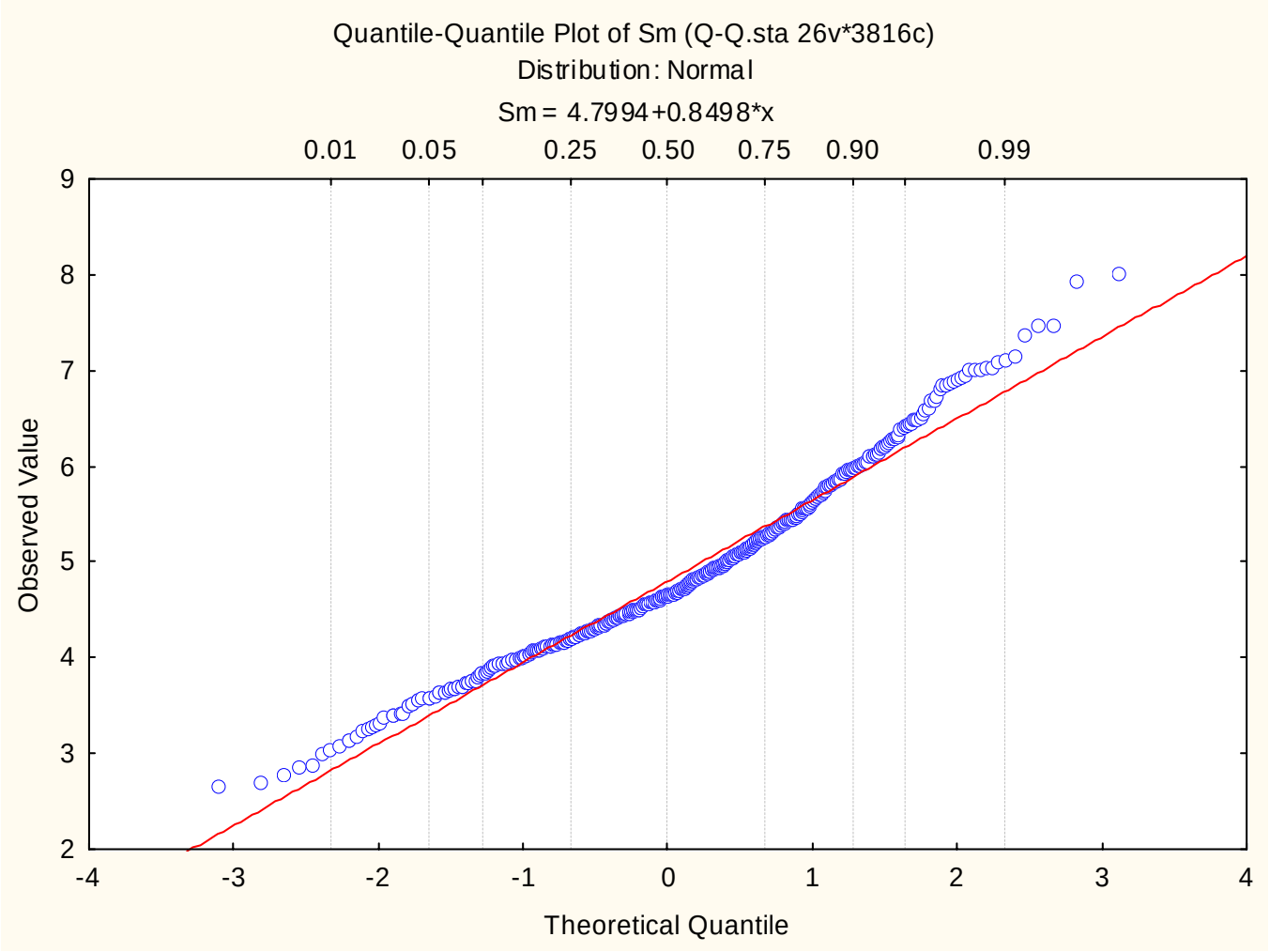

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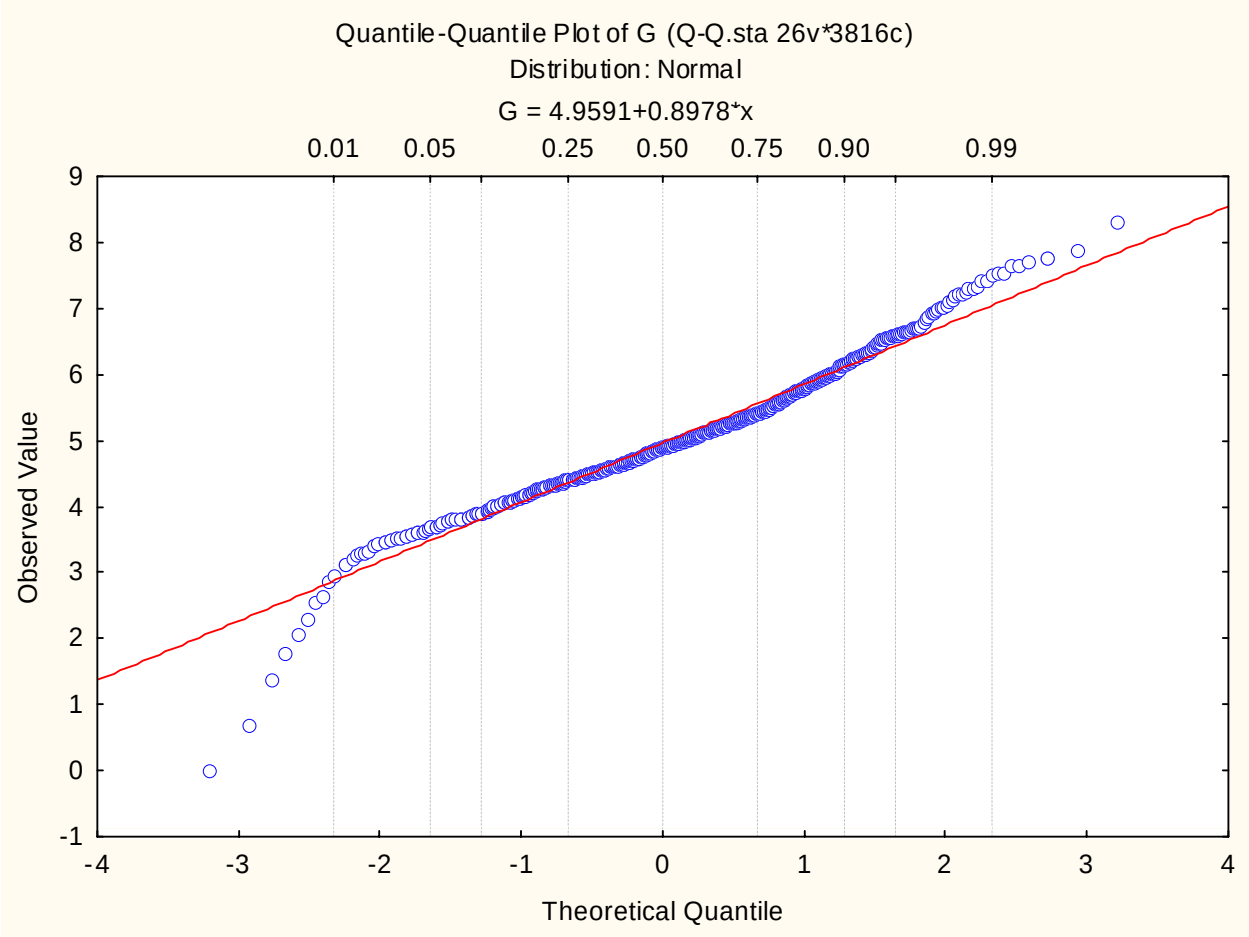
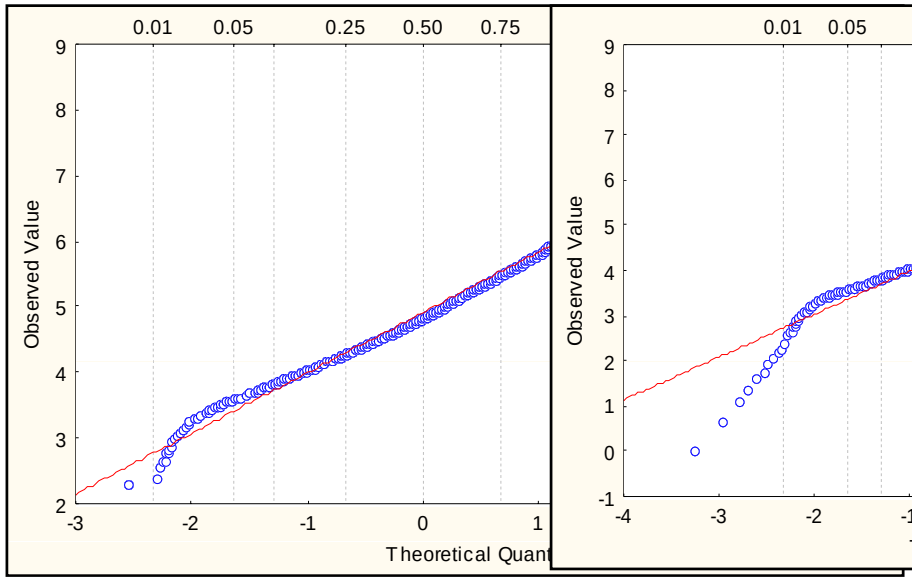
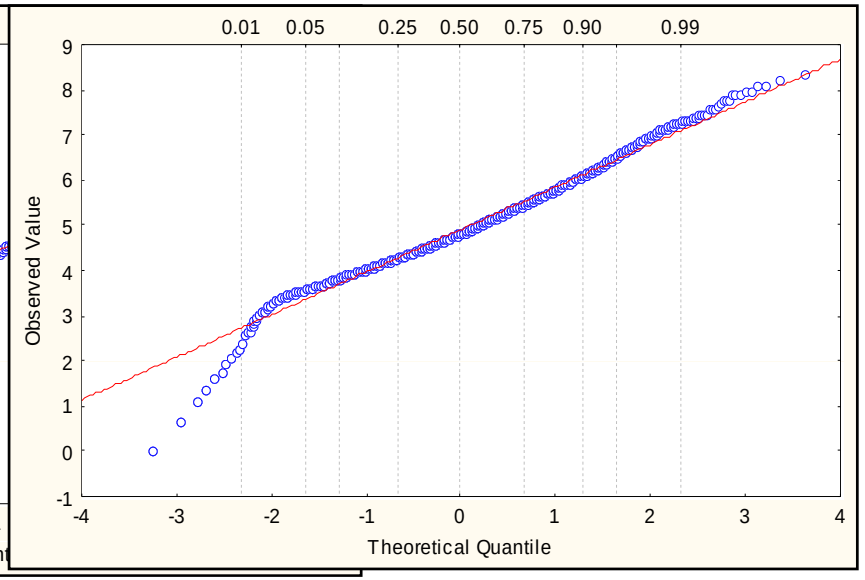


- **Low values are highly uncertain :**
  - Background subtraction can be inaccurate
  - How are the values < detection limit reported? (usually 6 to 10 Bq/m$^3$)
  - How are they included in the database?
  - Problem with negative results for Ln (measure<background)

All 10 Bq/m3

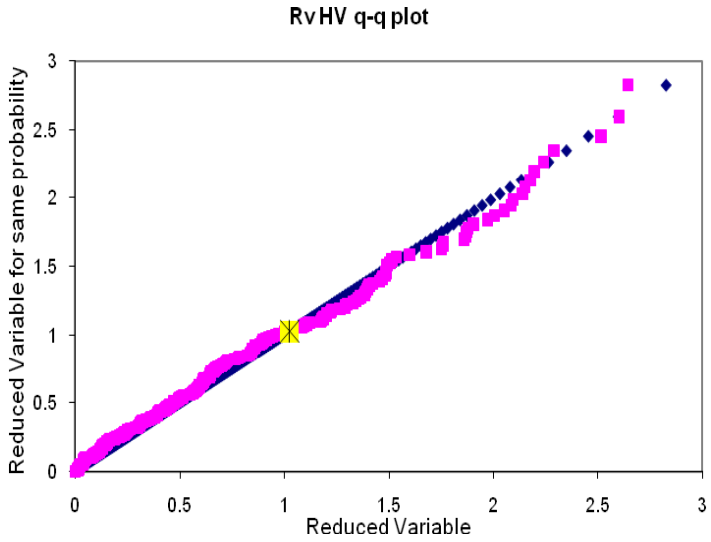


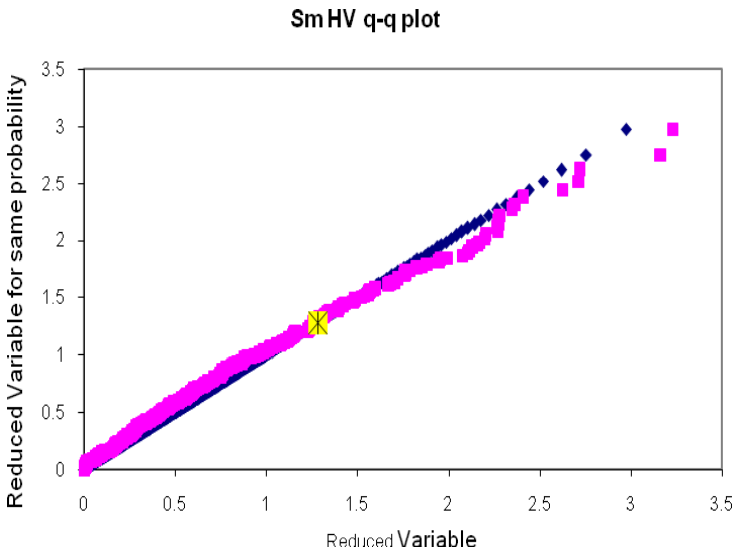

Uniform 1-10 Bq/m3

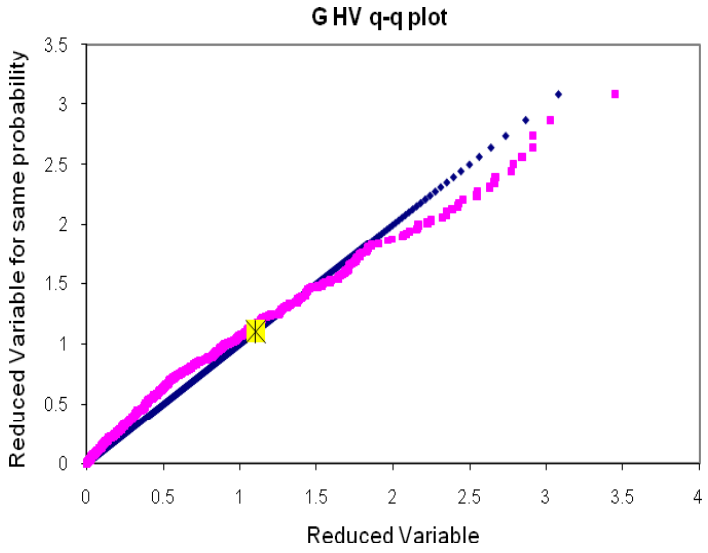


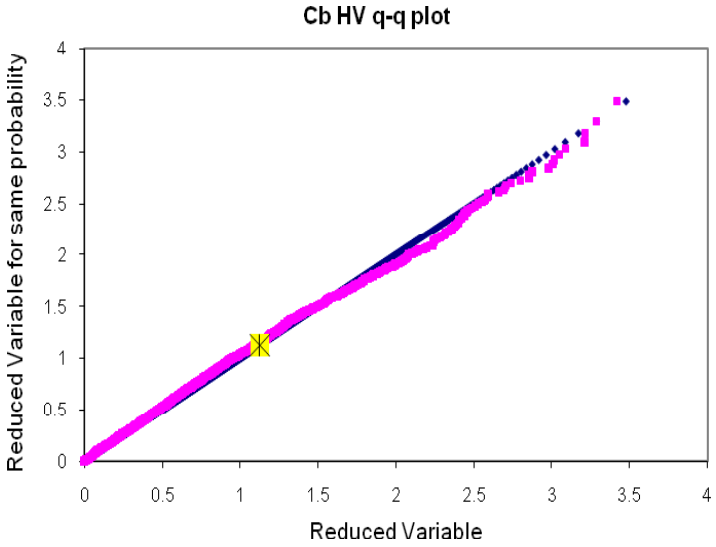

- **Low values influence LM and LSD**
- **Low values have no influence on the risk indicator (% above reference level)**

# High-Value Distribution



| Geological Groups | % above the Action Level (400 Bq/m³) | | |
|---|---|---|---|
| | Using observed data | Using HV Distribution | Using Log-Normal Distribution |
| **Revinian(Rv)** | 14.95 | 15.22 | 14.42 |
| **Salmian(Sm)** | 9.84 | 9.99 | 9.18 |
| **Gedinnian(G)** | 12.23 | 13.47 | 12.48 |
| **Siegenian(Cb)** | 12.44 | 13.00 | 12.24 |
| **Emsian(Bt)** | 9.35 | 9.70 | 7.89 |
| **Couvinian(Co)** | 5.44 | 6.10 | 5.79 |
| **Frasnian(Fr)** | 1.21 | 0.27 | 0.12 |
| **Famennian(Fa)** | 0.66 | 0.65 | 0.55 |
| **Trias-Jurassic (Tr-Ju)** | 1.40 | 0.59 | 0.25 |
| **Eocene (Eo)** | 0 | 0.05 | 0.03 |

First Conclusion:

Both distributions give reasonable results!

HV is a bit better, it overestimates the percentage by an average 0.15%

Log-N underestimates the percentage by an average 0.49%

# Logarithmic Standard Deviation: Local versus Global

## State of the art

To evaluate the percentage above the Action Level in each node of the grid, assuming a Log-normal distribution:

Use of the **global logarithmic standard deviation** (Cinelli et al., 2010)

Use of the **local GSD** calculated considering the data taken for each node (Miles and Appleton, 2005)

## Present Study

Comparison between the Log-Normal and Log-Normal HighValue distributios considering:

a) The Local LSD calculated in each node with the mentioned number of data;

b) The Global LSD, calculated from all data of the geological group;

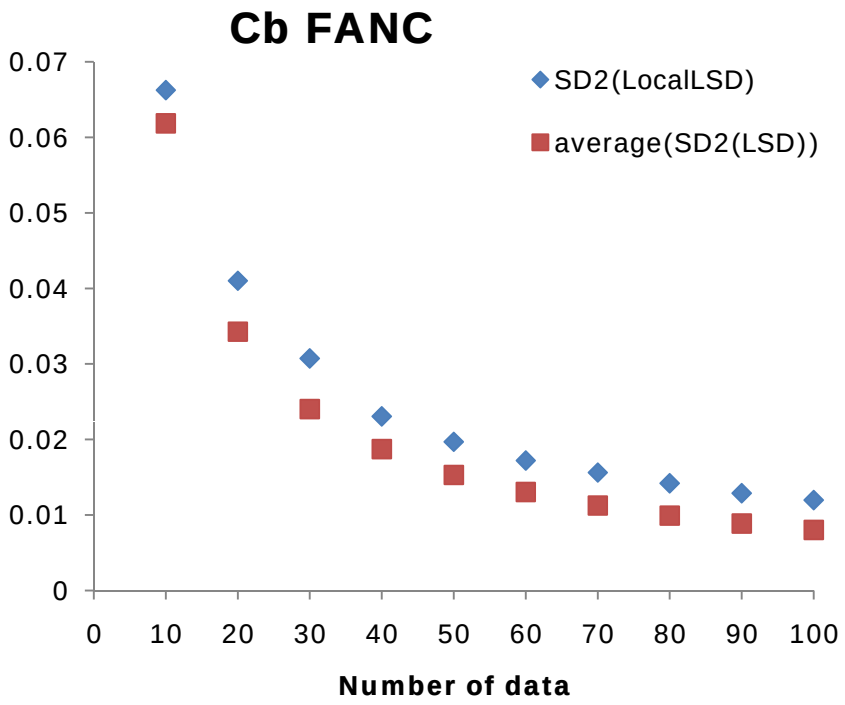
c) The Average of Local LSDs.

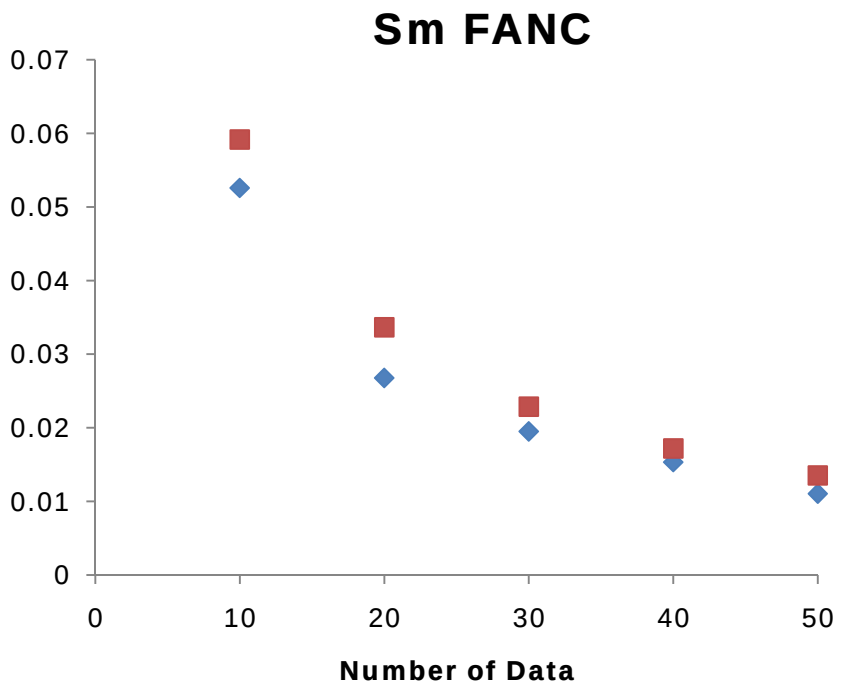
## Are the variation of the Local LSD significant or only random fluctuations?

The statistical variace of the LSD

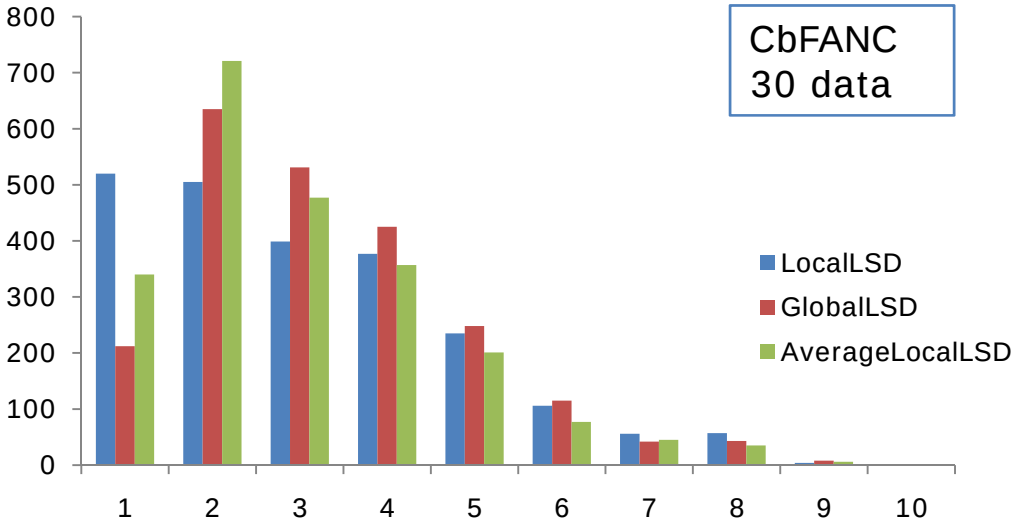
$$\sigma^2(LSD) = LSD^2 / N$$

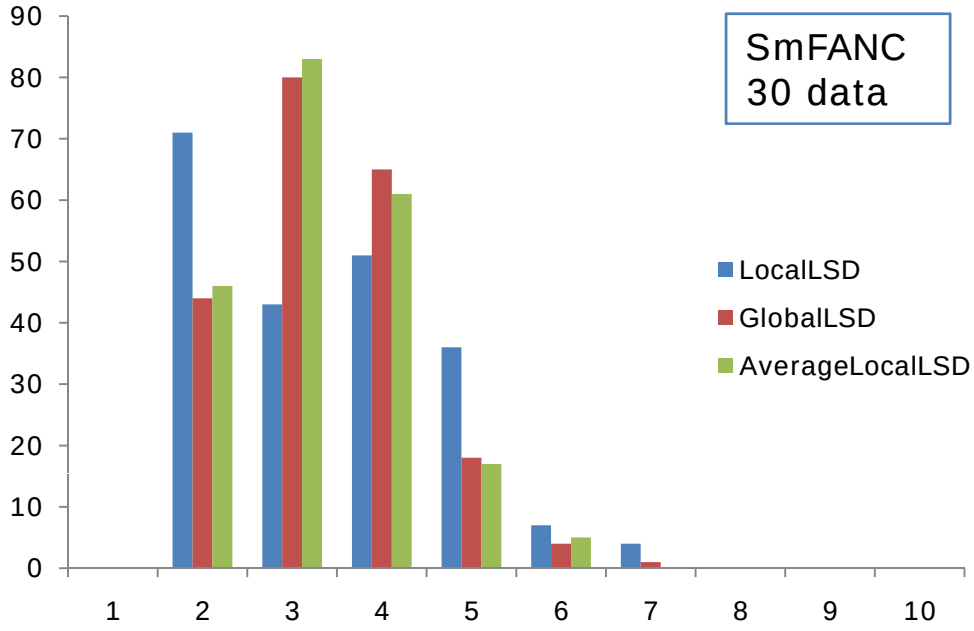
N= number of local data



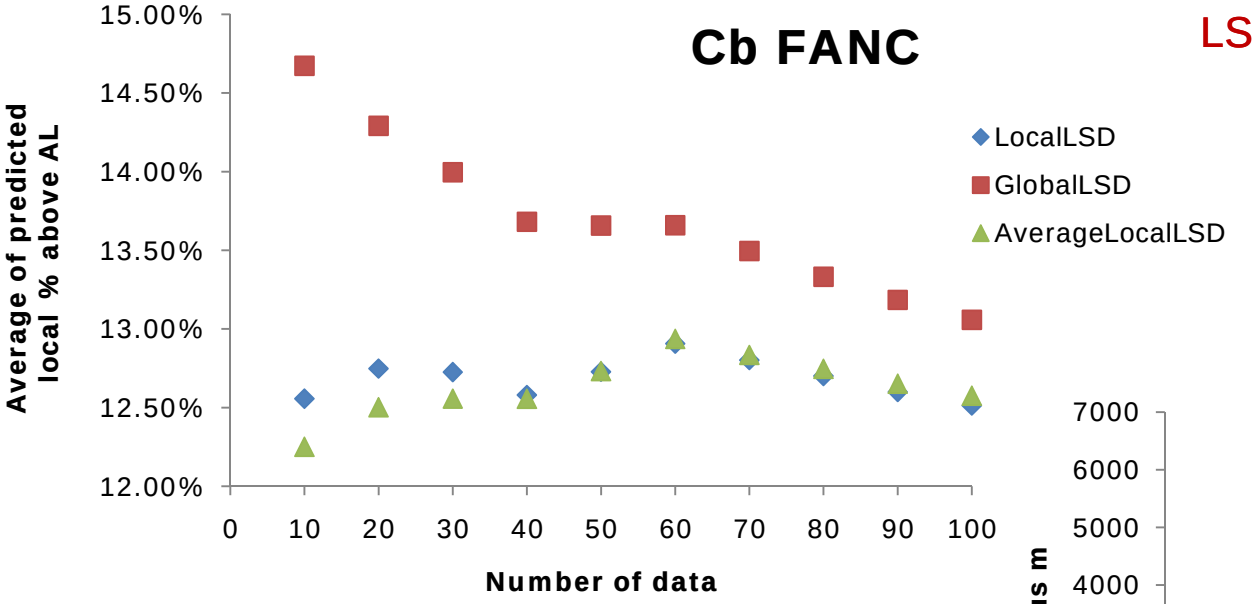
# LSD: Average Local versus Local

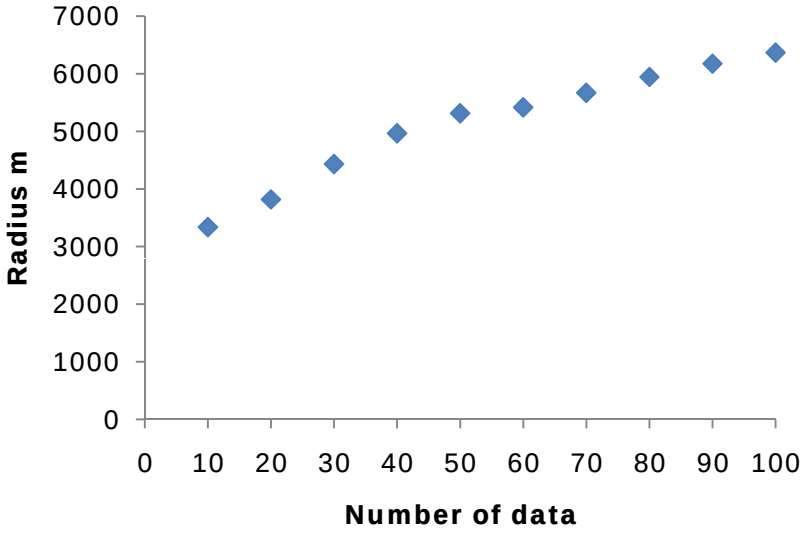


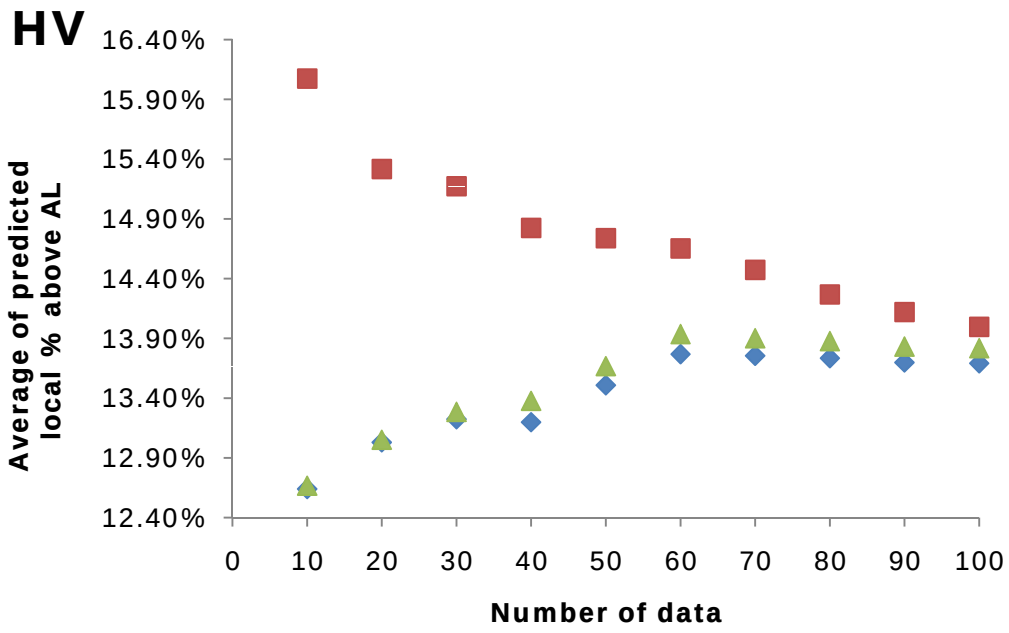




| Classe | % |
|---|---|
| 1 | 0-5 |
| 2 | 5-10 |
| 3 | 10-15 |
| 4 | 15-20 |
| 5 | 20-25 |
| 6 | 25-30 |
| 7 | 30-35 |
| 8 | 35-40 |
| 9 | 40-45 |
| 10 | >45 |

# LSD: Local versus Global



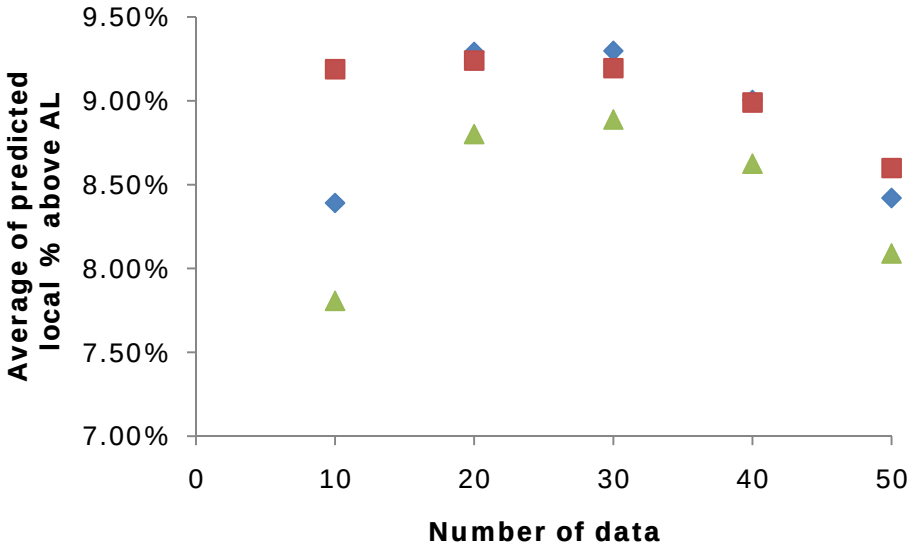



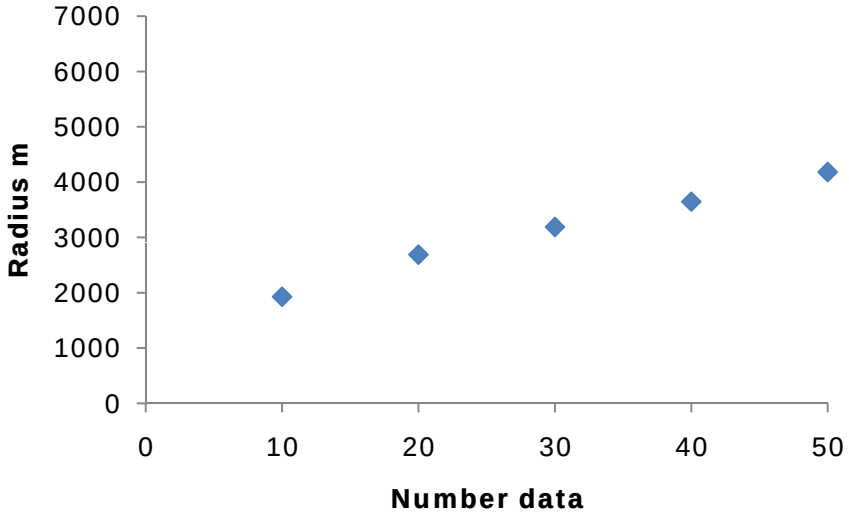



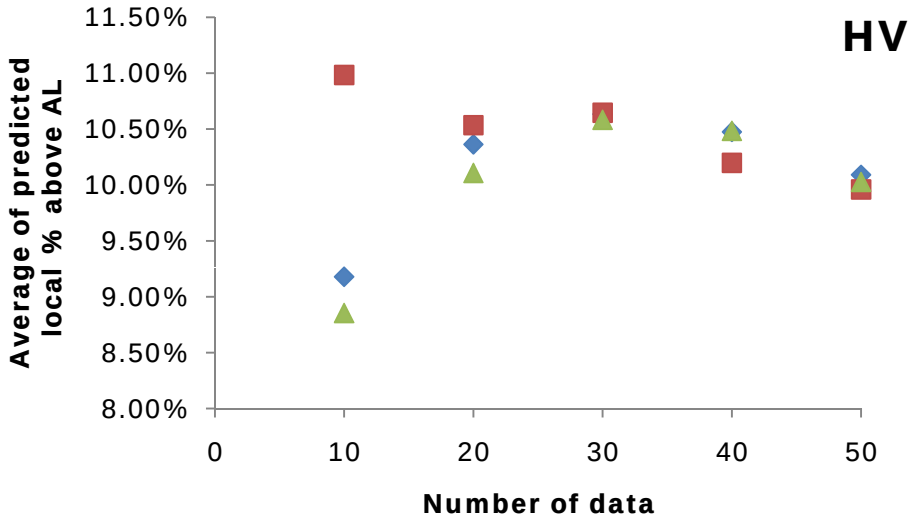

% above the AL using observed data

**12.44**

# LSD: Local versus Global




% above the AL using observed data

**9.84**

# Conclusions

**The results obtained shows that in general the log-normal distrubution (log normal high values distribution) well describes indoor radon data organized in geological unit to predict the percentage above the Action Level.**

**The log-normal distribution has the advantage of the availability of more tools compared to the extreme value distributions**

**The Local percantage above the action level can be estimated using between 20 and 30 indoor data and the Average Local Logarithmic Standard Deviation.**

Thank You

For Your Attention