WHY INDOOR RADON DATA ARE NOT LOG-NORMAL, BUT MAY SOMETIMES BE APPROXIMATELY

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Rn log-normality:
not the first time in GARRM

- Kies, Feider, Biell, Rowlinson 1994
- Toth, Hamori, Minda 2006
- Tuia, Timonin, Gruson, Piller, Maignan, Kanevski 2006
- Cinelli and Tondeur 2010
- Daraktchieva and Miles 2010

Present work:

1. Simulation based on simple hypotheses
2. Observed global distribution
3. Observed distribution in homogeneous geological units

There are several common points, but also differences, between the present work and Daraktchieva, Miles & McColl, 2014, Journ. Radiol. Prot., 34, p.183.

Indoor Rn should not be log-normal

- Central-limit theorem:
  a random variable is log-normally distributed if it is the product of many independent random factors

$$V = \prod_i f_i$$

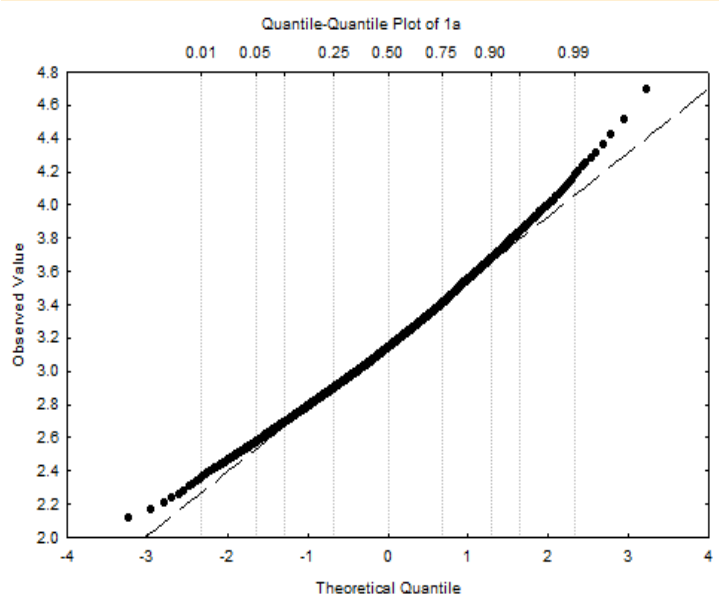
- Indoor radon is the sum of three such variables: Rn from soil, materials and outdoors

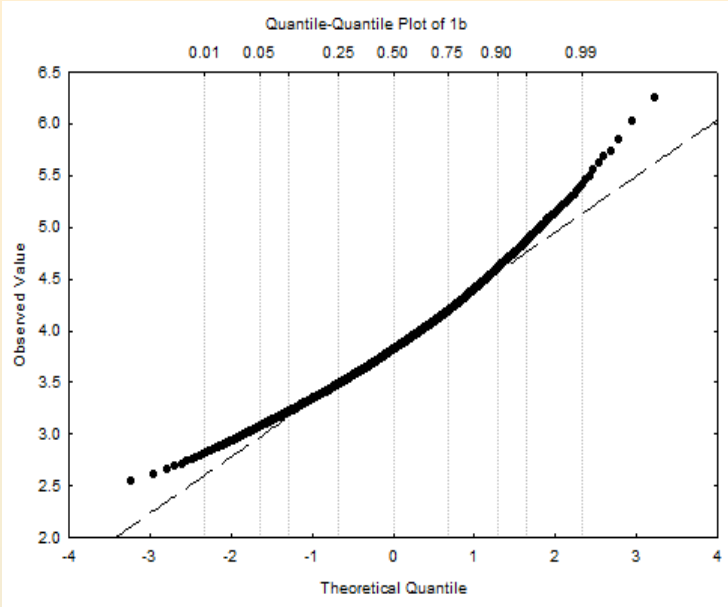
$$C = \prod_{soil} f_{i,soil} + \prod_{materials} g_{i,mat} + \prod_{outdoors} h_{i,out}$$

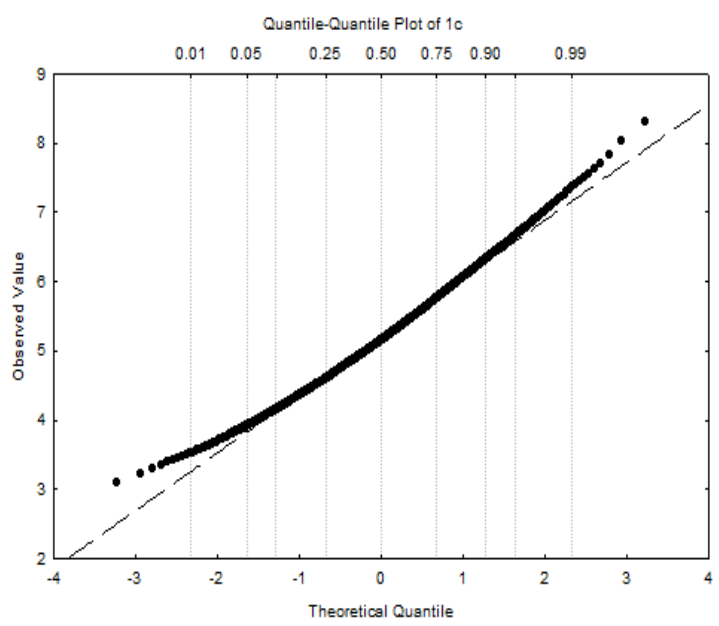
- Could be lognormal if one component is dominant

Simulation
How could log(C) be distributed?

- Hypothesis:
  each of the 3 components is lognormal
- Arbitrary, but not unrealistic parameters:
  log. mean (geom.mean) log.standard deviation
  - Outdoors : LM=2 (GM=7 Bq/m^3) LSD=0.3
  - Materials : LM=2.6 (GM=13 Bq/m^3) LSD=0.6
  - Soil : LM=0/3/5 (GM=1/20/148 Bq/m^3) LSD=1.0
- Deviations of log(C) from normality best shown with the normal plot (or q-q plot): observed vs. expected







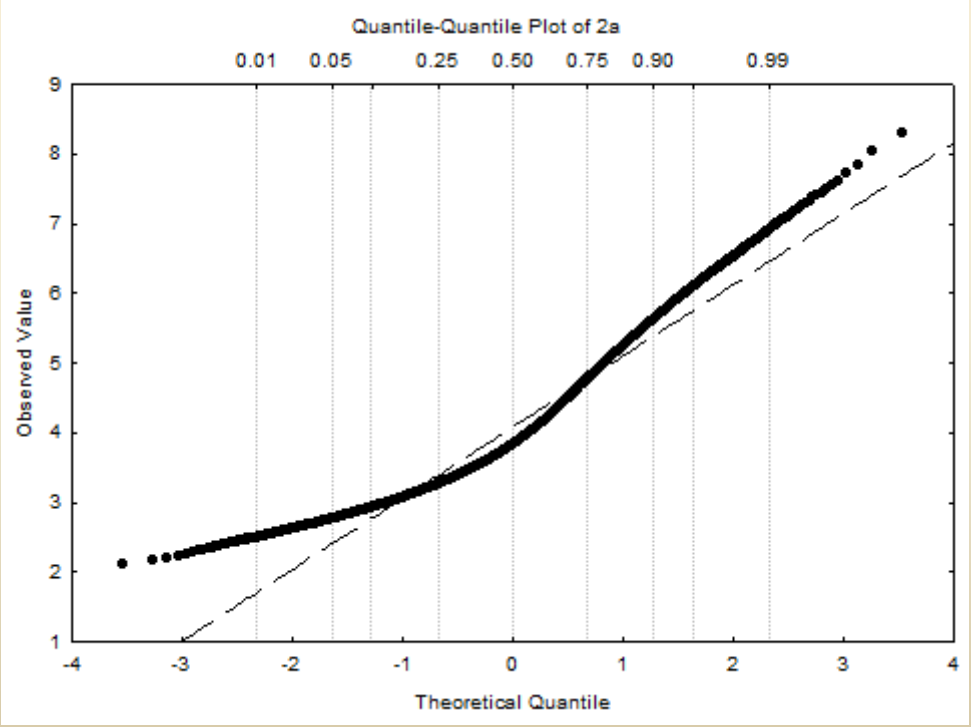
Low values as well as high values are higher than expected if lognormal

« slim » low-C tail
« fat » high-C tail

« Multimodal » case

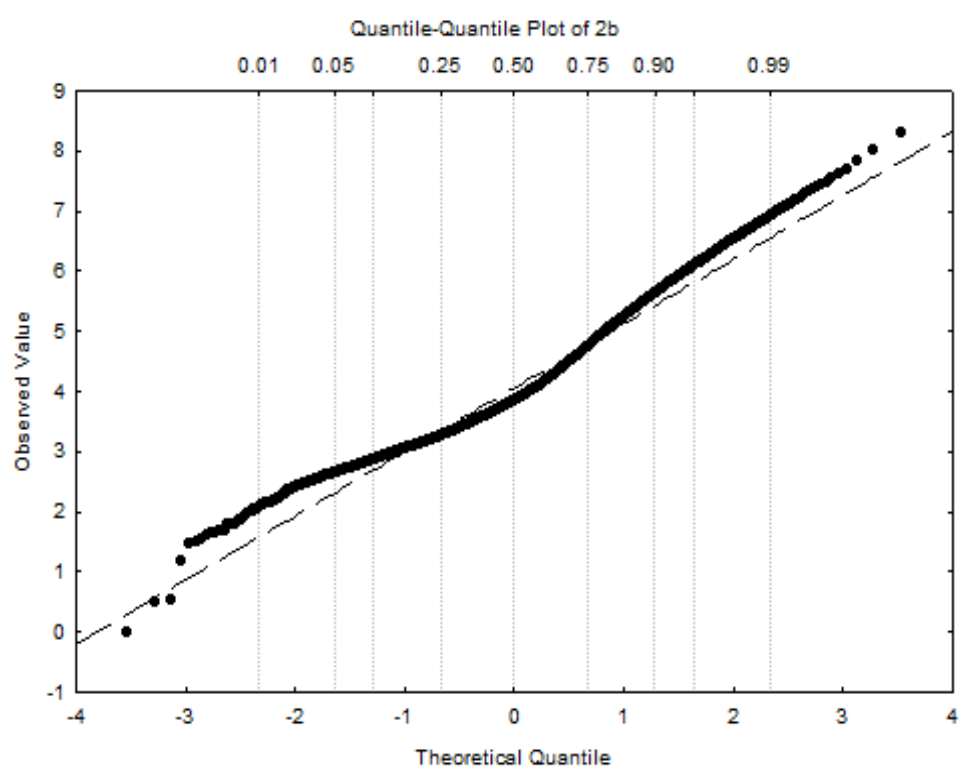
Combination of the three groups with soil Rn GM=1, 20, 148 Bq/m^3

Low-C slim-tail stronger



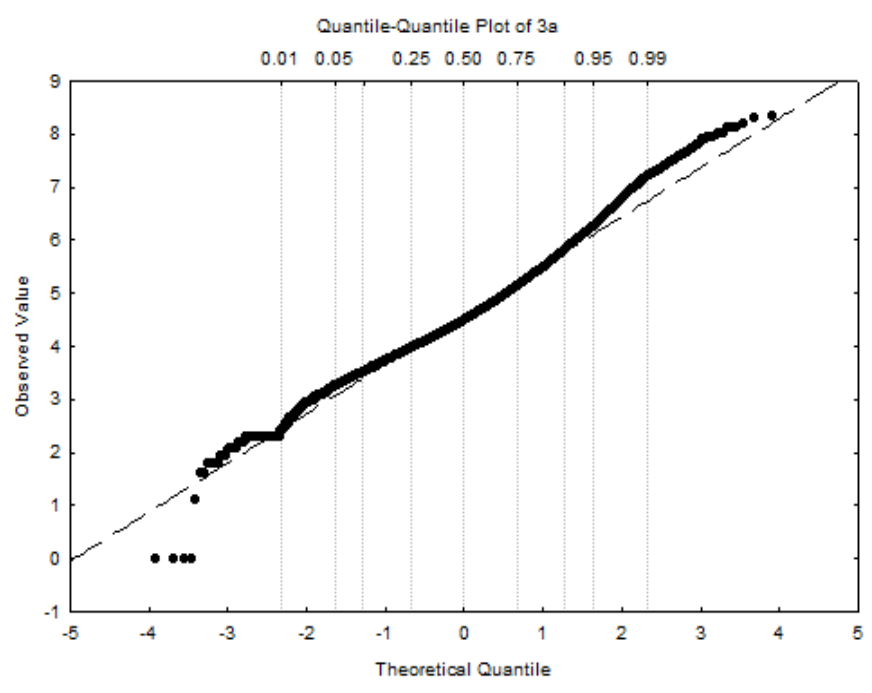
Effect of measurement uncertainties

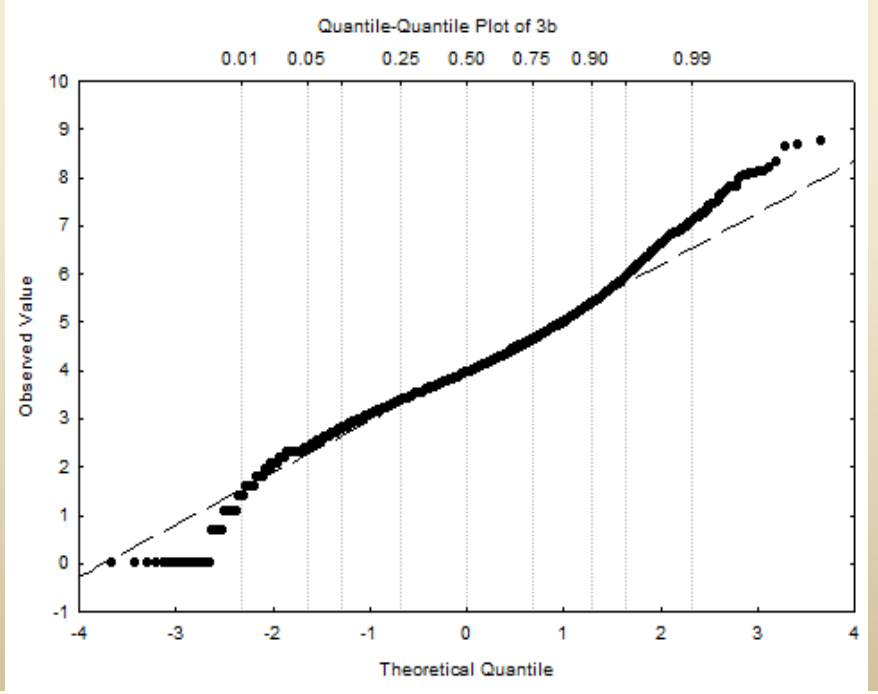
- Add a normal noise to C , SD=5 Bq/m^3
- Dramatic change in the low-C tail



Observed global distributions

- Walloon region (Belgium)
- 18872 ground floor Rn measurements
- Left: 75 % long term (3 month) track-etch
- Right: 25 % short term (3-4 day) charcoal
- The major trends predicted by the model are reproduced
- Low-C tail dominated by measurement uncertainties and reporting problems, which mask the low-C components





When can we use the lognormal distribution?

- When one component dominates
- Not on the low-C side
- Ex.1: (?) upper floors of tuff-built houses in Lazio, Italy
- Ex.2: high-C cases in homogeneous Rn-affected areas (single mode in which soil Rn dominates)

- We only consider data above the median
- 10 Rn-homogeneous units in the Walloon region with the highest GM ≥110 Bq/m^3

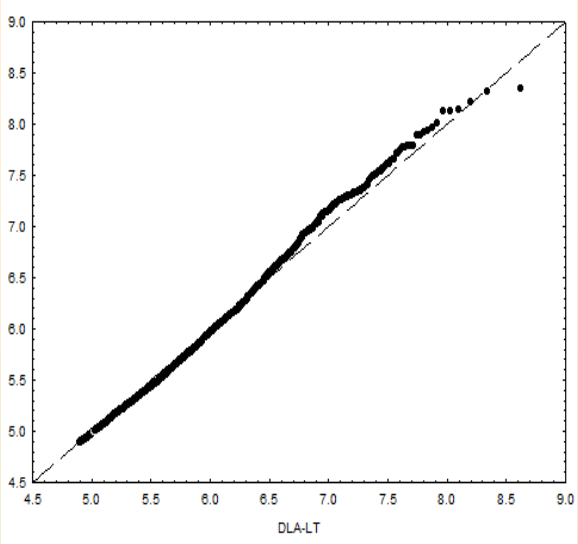
Cambrian CST-LT CST-ST CUB-LT CUB-ST

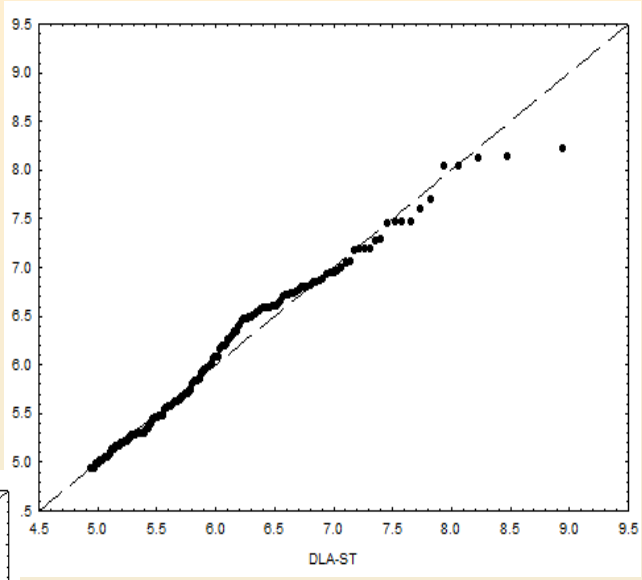
Ordovician OST-LT OST-ST ODY-LT

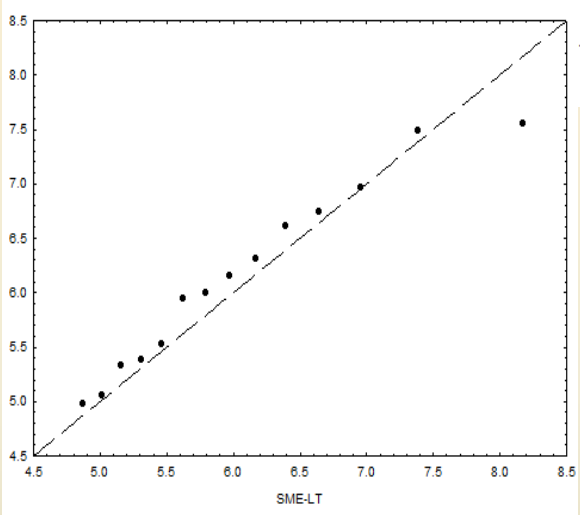
Silurian SME-LT

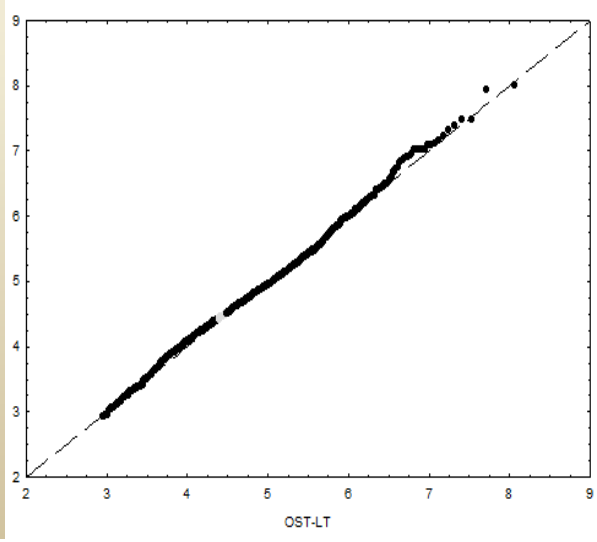
Lower Devonian DLA-ST DLA-LT

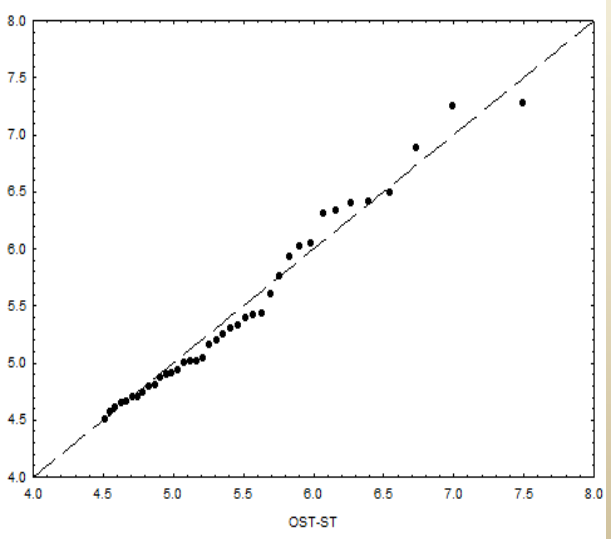
GM > 110 Bq/m^3

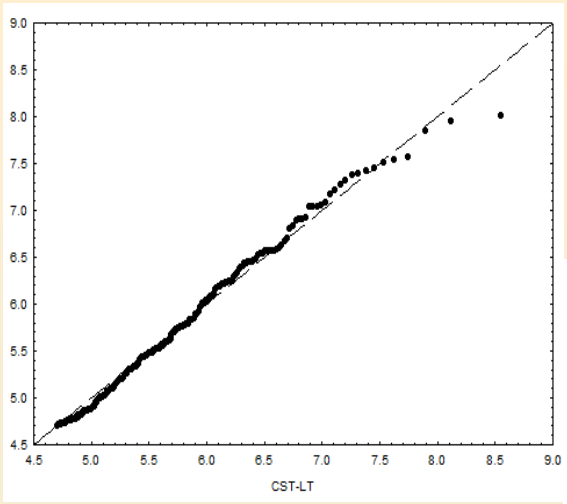




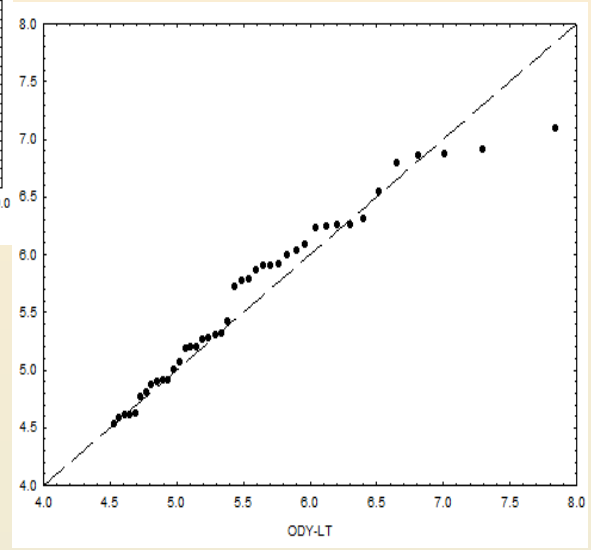


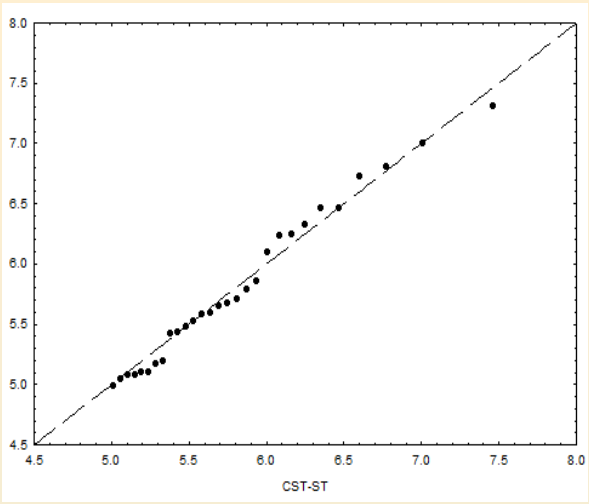


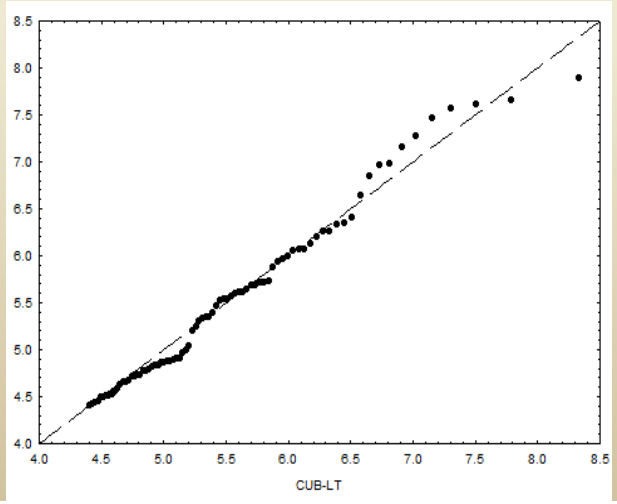




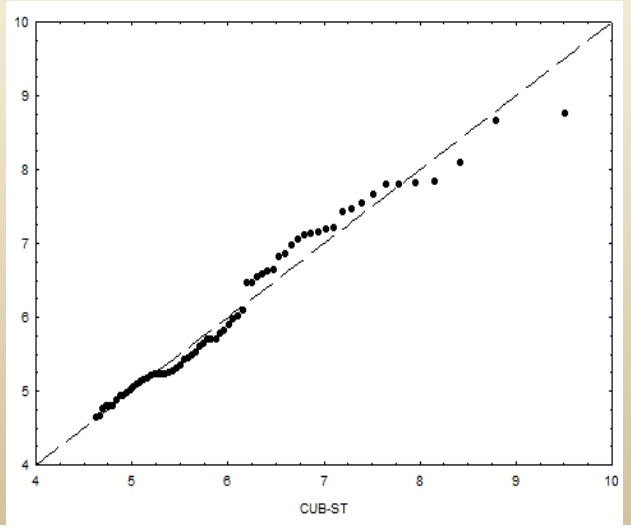
GM > 110 Bq/m^3



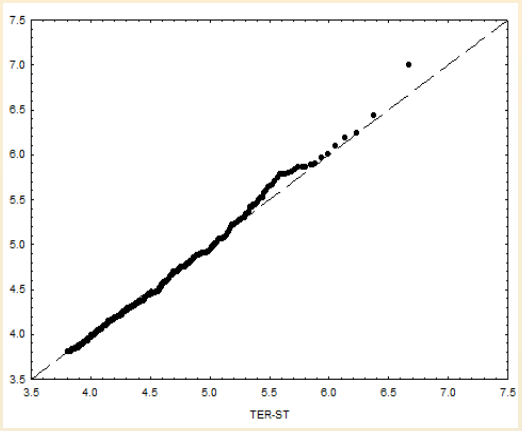


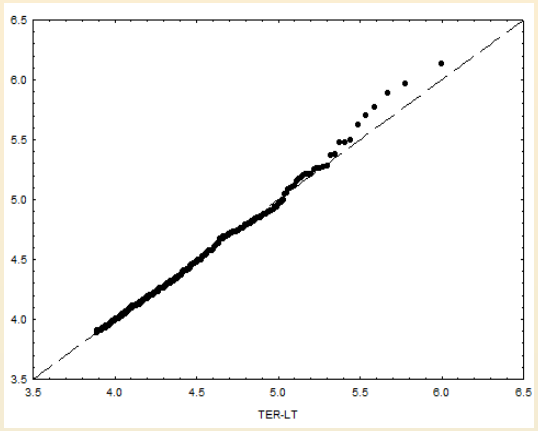


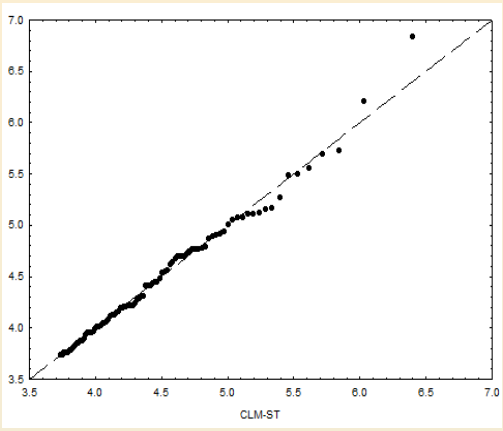
Rather good LN trend
Fat tail not important
No high-C outlier
Extreme tail is slim
Consistent with LN
for soil component



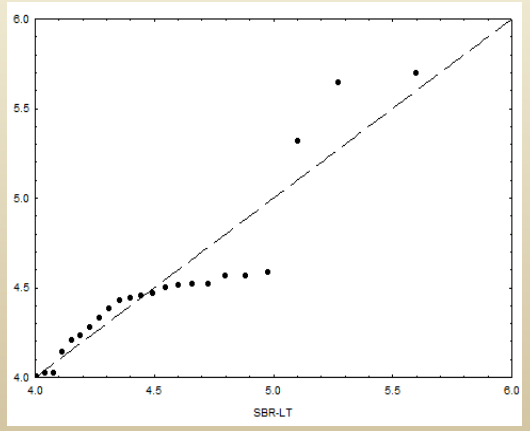
GUs with GM<50 Bq/m^3

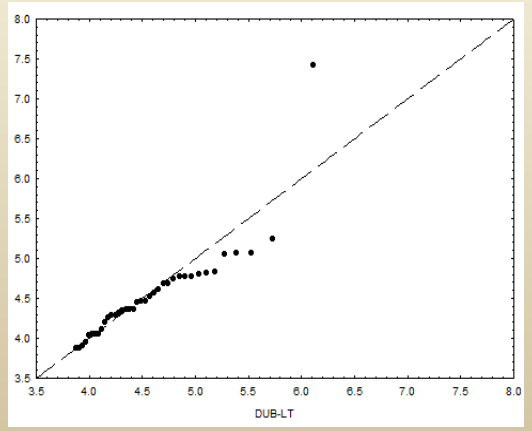


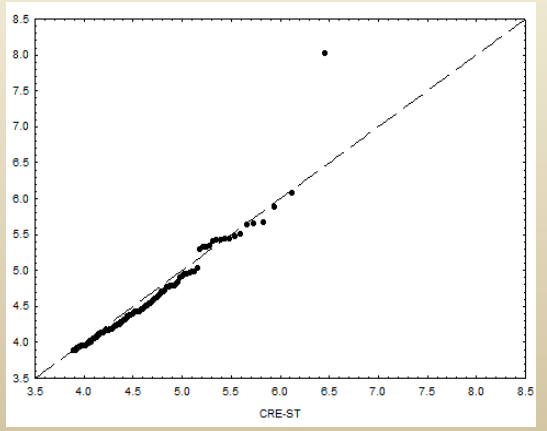




- Some still have a rather good qq-plot, slight fat tail
- Other show a non-LN trend, several include high-C outliers
- Extreme tail always fat







Conclusion

- Deviations from the log-normal distribution, like the fat high-C tail, are explained by the 3-component structure of indoor Rn
- The low-C tail is dominated by measurement uncertainties
- The high-C tail, above the median, follows rather well the LN trend in affected areas, not so well in unaffected areas
- The data do not contradict the hypothesis that the soil component of indoor Rn in Rn-homogeneous geological units is LN