Can citizen science generated ambient dose rate data (*Safecast*) be used for predicting indoor radon?

Bossew P.[1], Cinelli G.[2], Petermann E.[3], Kuča P.[4], Helebrant J.[4]

1 Privatier, Vienna, Austria

2 ENEA, Palermo, Italy

3 Bfs, Berlin, Germany

4 SÚRO, Prague, Czech Republic

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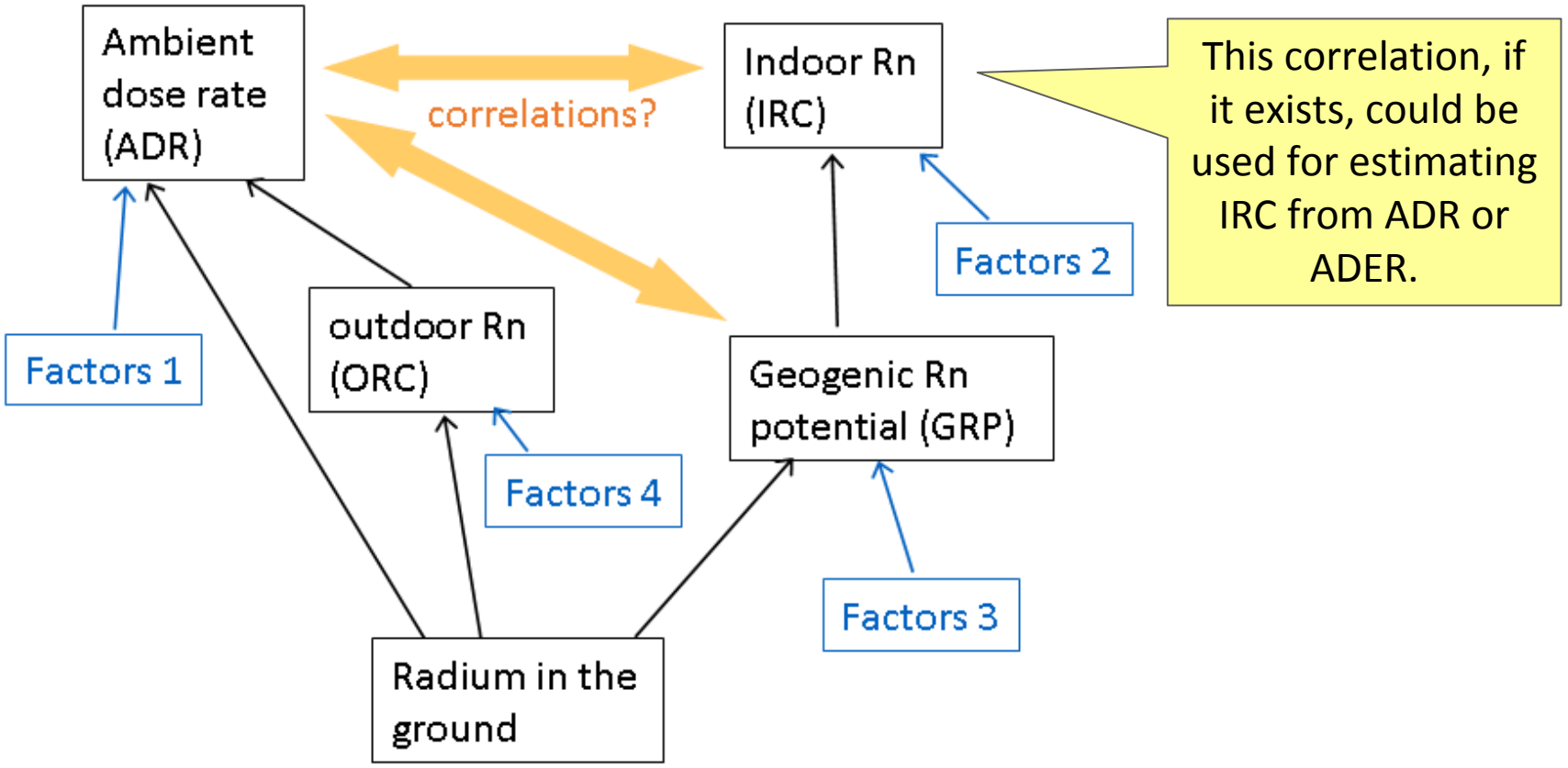
Research question

- Large amount of ambient dose equivalent rate (ADER) data generated by the *Safecast* project available;
- Can the data be used for predicting quantities that are relevant in radon abatement policy, such as
  - regional mean indoor Rn concentration (IRC)?
  - regional probability that IRC exceeds a reference level (RL)?
  - the status of an area as Rn priority area (RPA*)?

* Areas in which Rn abatement (prevention, mitigation, remediation) is considered necessary due to elevated Rn levels.

Rationale

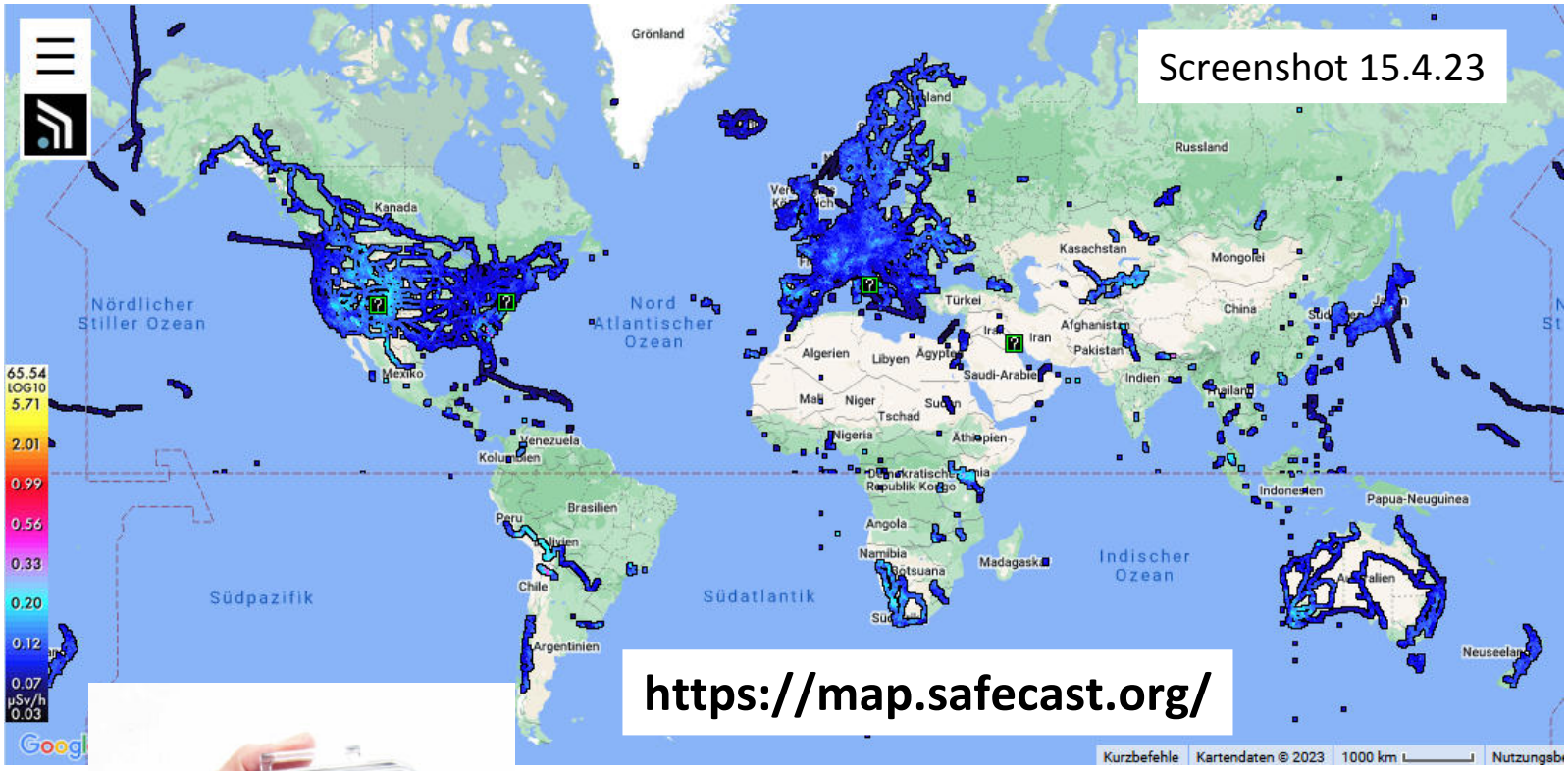


Various “nuisance” factors blur the correlation: cosmic dose rate, outdoor Rn, other sources of terrestrial dose rate (^{40}K, Th series), factors which control ingression of Rn into buildings.

Safecast

- Citizen Science project, founded in Japan after the Fukushima accident, 2011; quickly expanded world-wide;
- A monitor called "*bGeigie Nano*" used, several thousand units carried by volunteers for collecting ADER data;
- Data can be sent to the *Safecast* team, who projects it on a publicly accessible map;
- By early 2023: about 200 mill. data in the database, about 50 mill. in Europe. Data can be downloaded.

Safecast map



bGeigie Nano: GM detector, coupled to GPS. Output: ADER, nSv/h

Data saved on SD card in txt format.

Data

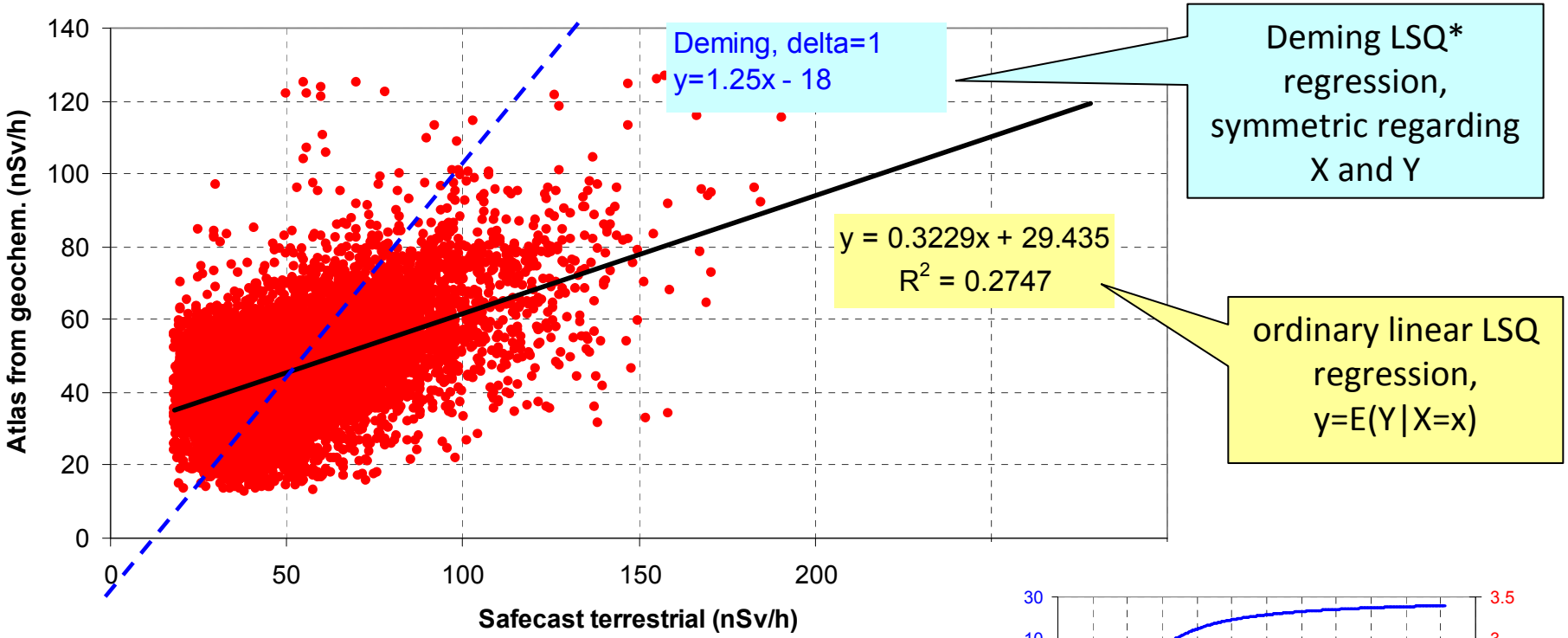
- *Safecast* data
  - n=52,887,234; relevant fields: coordinates, ADER (1 minute mean, µSv/h).
  - Processing: internal background removed; cosmic dose rate subtracted, calculated from altitude, taken from DEM → terrestrial ADR, conversion of geographical into European Lambert coordinates, aggregation into European grid, 21,828 cells.
- European indoor radon database, from the European Atlas of Natural Radiation (2019) [1]:
  - about 1.2 mill. measurements, aggregated into 10 km × 10 km cells.
  - Statistics: AM, SD*, AM and SD of ln-transformed data, min, median, max, N (data per cell). n=29,539 cells
  - Exceedance probability prob(IRC>RL)* can be calculated.
- Geochemical database from the Atlas:

  from U, Th, K concentrations terrestrial ADR (nGy/h) calculated. Converted into ADER (nSv/h). Same grid. n=12,101 cells

[1] https://remon.jrc.ec.europa.eu/About/Atlas-of-Natural-Radiation

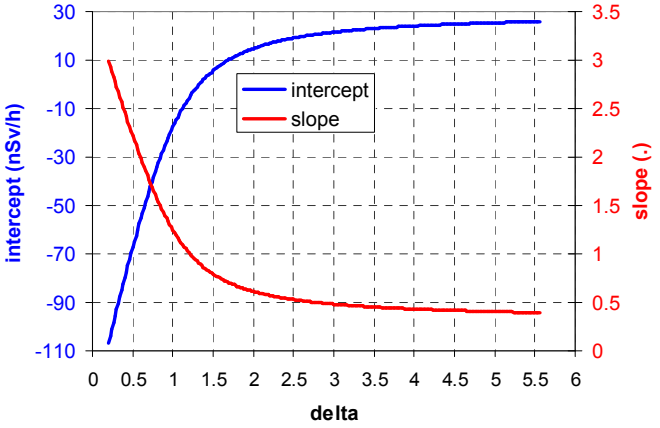
* AM, SD – arithmetical mean, standard deviation; RL – reference level

Comparison ADER Safecast / Atlas



Deming LSQ* regression, symmetric regarding X and Y

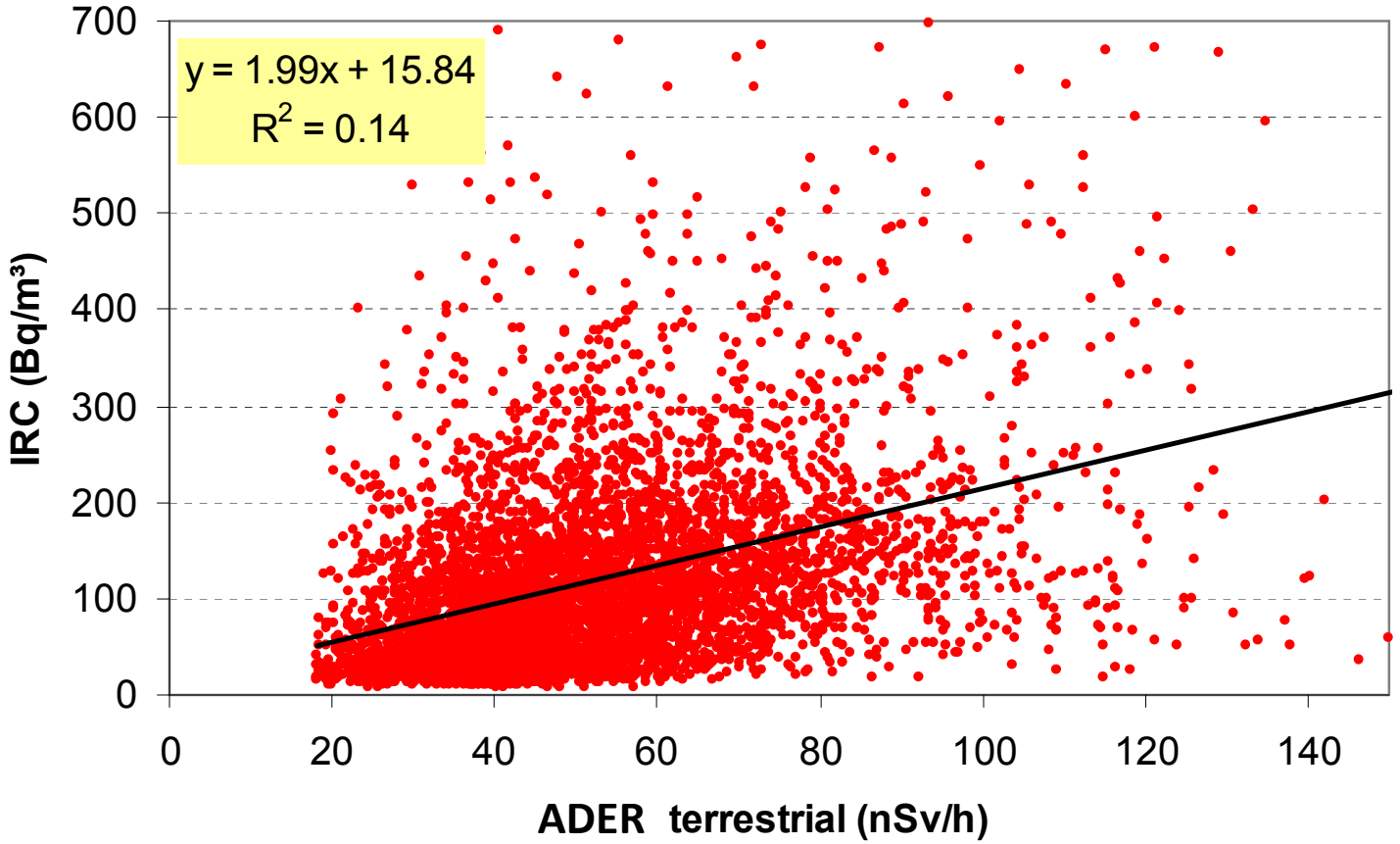
ordinary linear LSQ regression, y=E(Y|X=x)



Problem: Both variables have uncertainty (in ordinary regression only Y) → Deming (orthogonal) regression.
Result is very sensitive against choice of $\delta := unc_y^2/unc_x^2$
Here tentatively $\delta=1$ chosen: result not convincing, requires further research! For $\delta \to \infty$: ordinary regression

* LSQ – least square

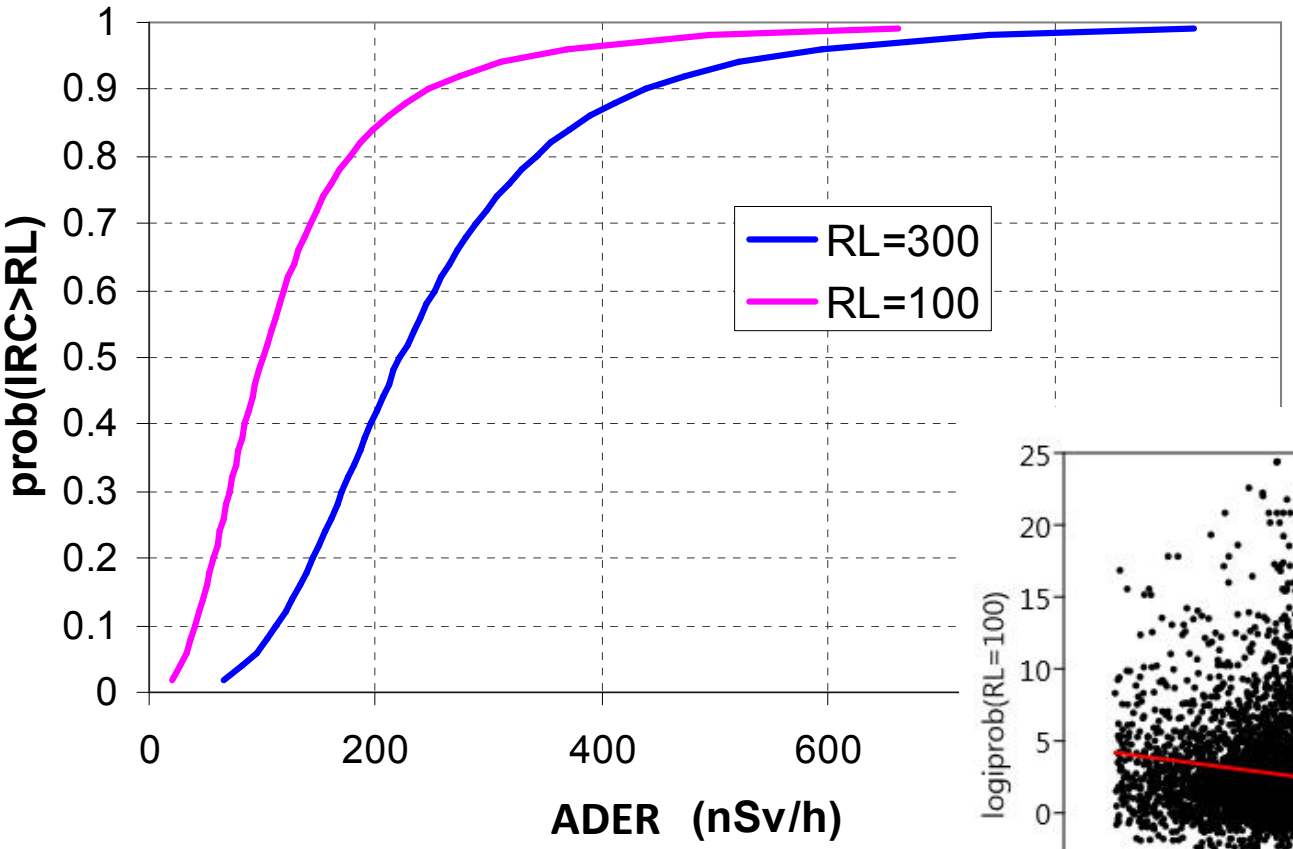
ADER Safecast – IRC mean per cell

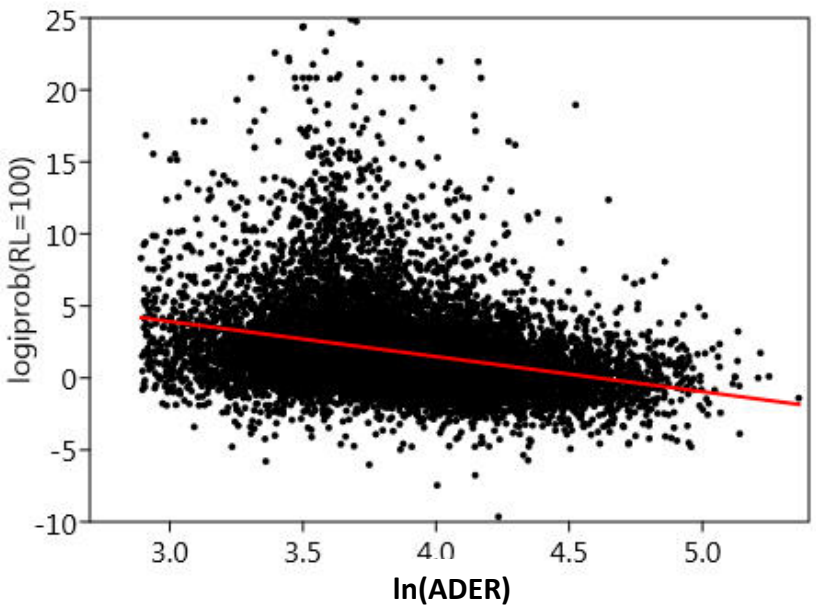


for IRC, only cells with n>10 used
uncertainty not yet considered

ADR Safecast – IRC exceedance probability

log-logistic relationship: $p=1/(1+b\,x^{-a})$

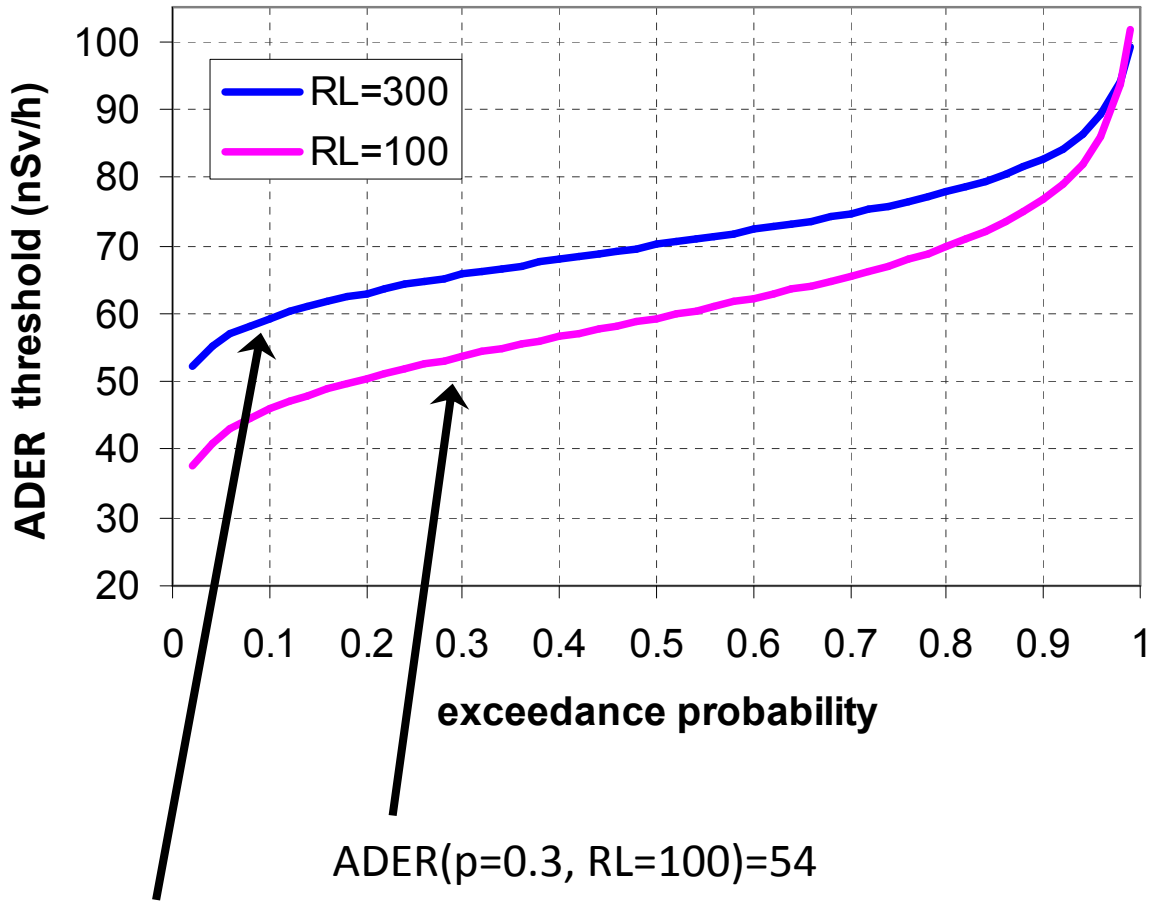




log-logistic relationship transformed to linear, y=a+bx,
y=logiprob(p):=ln((1/p)-1), x=ln(ADER)

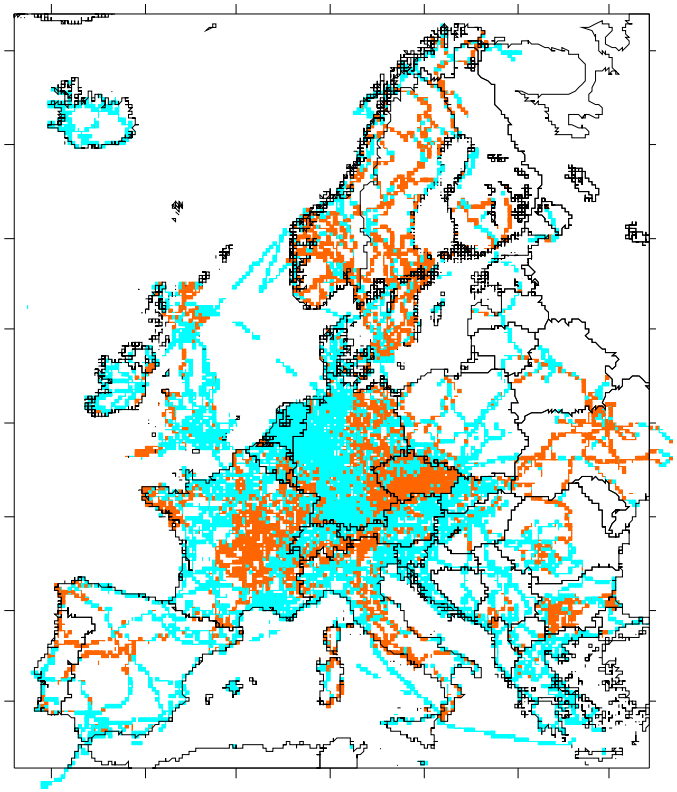
RPA: ADER thresholds by logistic regression

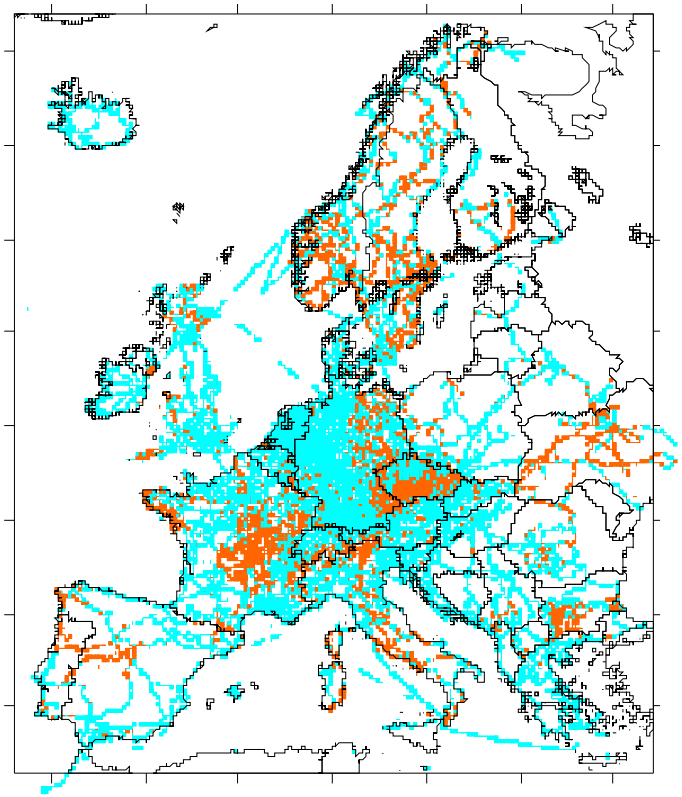
inverse log-logistic relationship: $y=e^{A}((1/p)-1)^{B}$



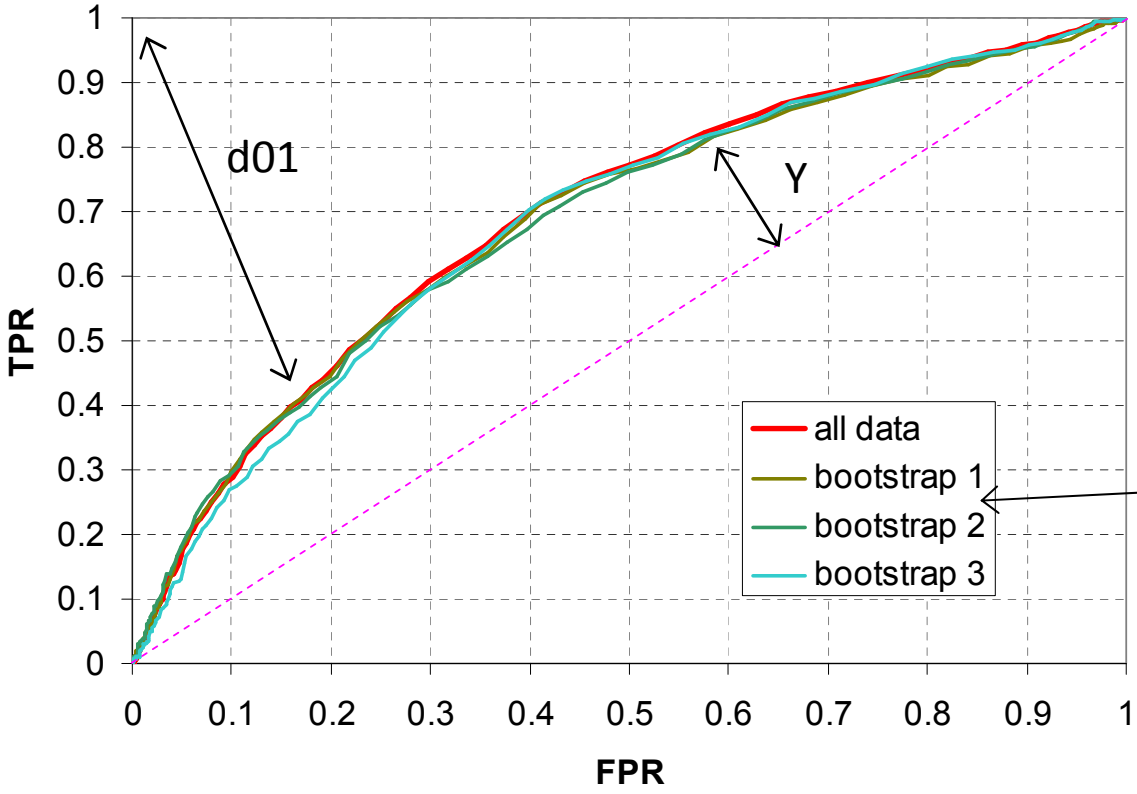
Estimating radon priority areas? (1)

- <u>Method 1:</u> Logistic regression.
- RPA: prob(IRC>100)>0.3 and prob(IRC>300)>0.1
  (red areas in the maps)





Estimating radon priority areas? (2)



Method 2: ROC, cross-classification, nonparametric

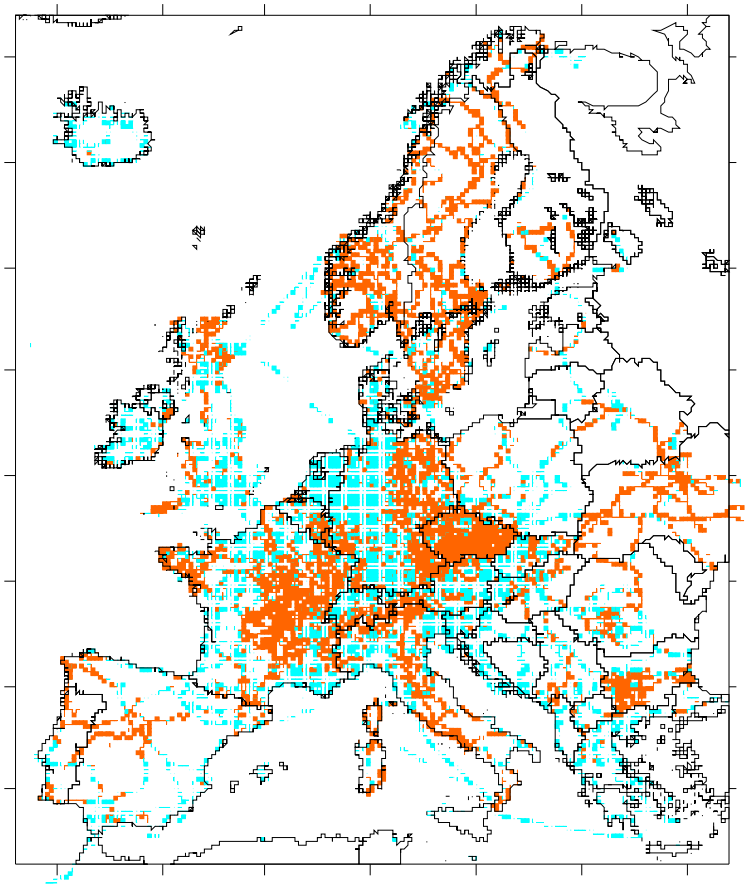
in order to assess the uncertainty of the ROC curve. Appears very reliable

thresholds of ADER, corresponding to the crit

TPR, FPR – true, false positive ratios
Optimal point in the ROC curve by optimizing statistics, e.g., finding the point on the curve which maximizes Y- or minimizes d01-statistic
AUC – area under curve, measure of strength of relationship.

crit	Y	d01	AUC
prob(IRC>300)>0.1	**49**	**51**	0.69
prob(IRC>100)>0.3	**48**	**48**	0.70

Estimating radon priority areas? (2)



prob(IRC>300)>0.1
threshold:
ADER terr.= 50 nSv/h
1.kind error prob≈ 40%
2.kind error prob≈ 30%
quite high!

RPA too large!
Method 1 appears more plausible, although method 2 is usually more robust.
Pattern essentially correct.

Conclusion

- Gridded *Safecast* ADER data appear plausible.
  Problem: *Safecast* data with unknown uncertainty, possibly serially correlated.
- *Safecast* and Atlas ADER are significantly correlated.
- Relationship between *Safecast* ADER and IRC related quantities exists, but not very strong.
- RPA over-estimated; high classification error probability

To do

- Better consideration of data uncertainty!
- Classification by type of environment, in which *Safecast* ADER has been measured: rural, sub-urban, urban
- Influence of number of measurements per Rn cell to be investigated.

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Thank you!

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Privatier
Physics & metaphysics en gros & en detail

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National Radiation Protection Institute