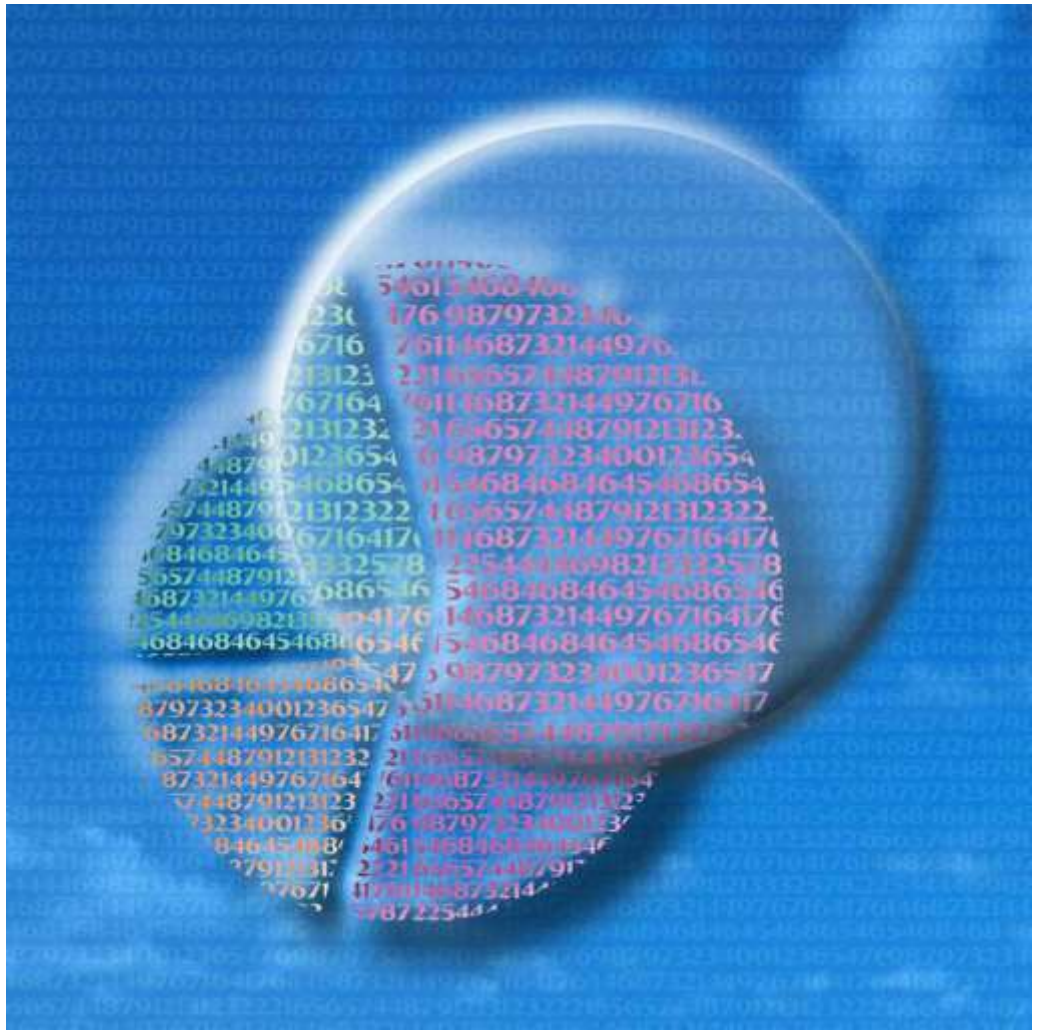


Wrap up

Andrea Saltelli
Centre for the Study of the Sciences and the Humanities, University of Bergen, and Open Evidence Research, Open University of Catalonia

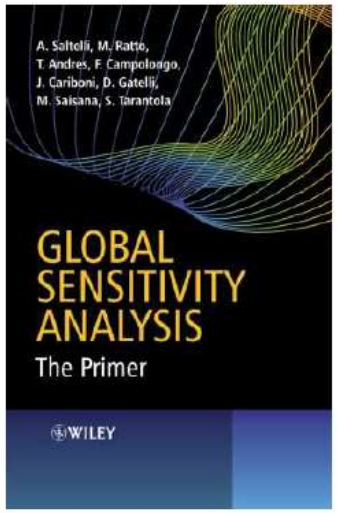
Summer School on Sensitivity Analysis – SAMO 2018

Ranco (Italy) - June 11-15, 2018
Conca Azzurra Hotel

A poll

Check Errata corrige

… and do the exercises!

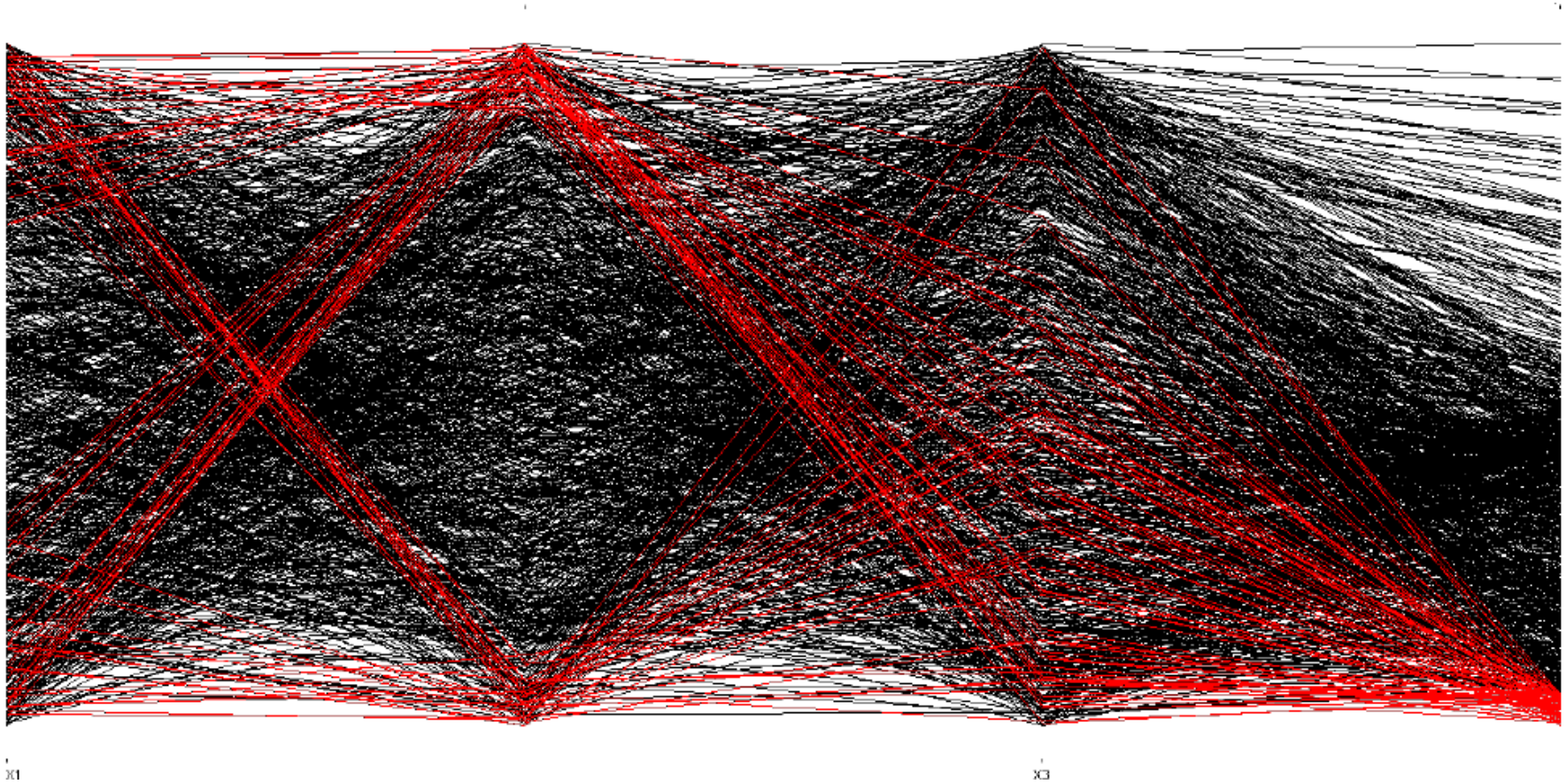


A corrected pdf copy under ‘resources’, ‘books’

Iooss B., and Saltelli, A., 2015, Introduction to Sensitivity Analysis,

to appear in Springer Handbook on Uncertainty Quantification, Editors: Roger Ghanem, David Higdon and Houman Owhadi

http://www.andreasaltelli.eu/file/repository/intro_v2b.pdf



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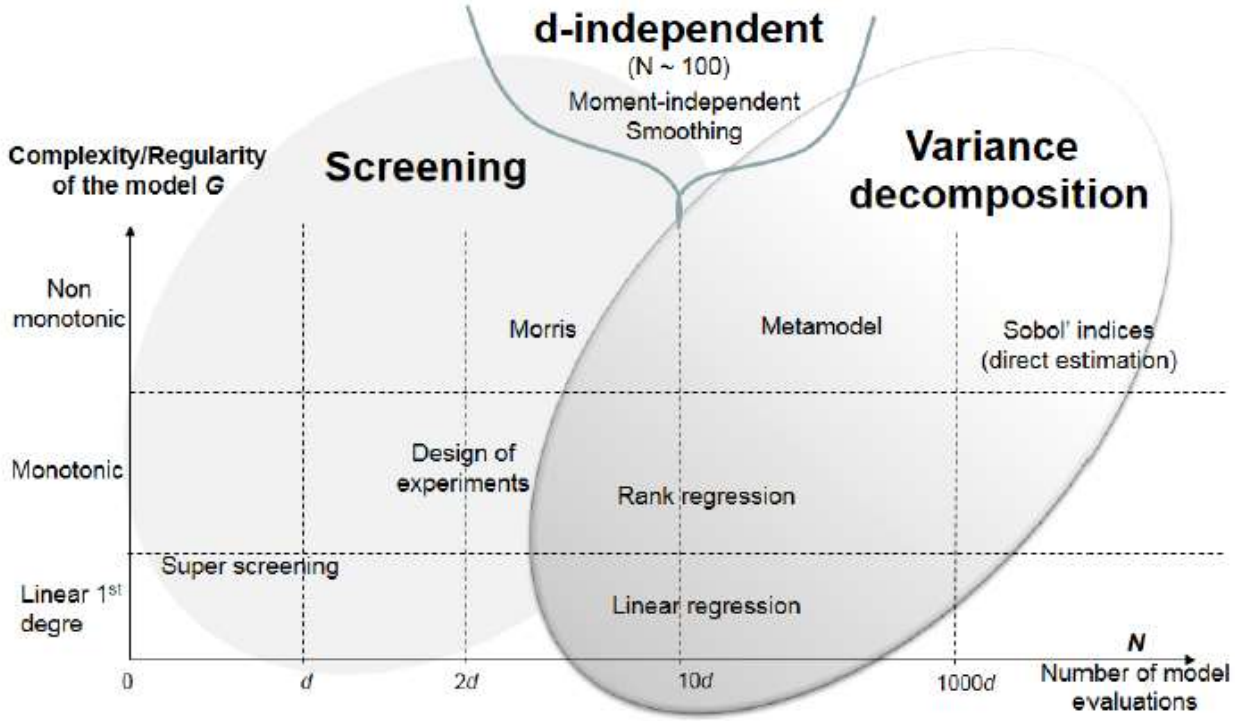
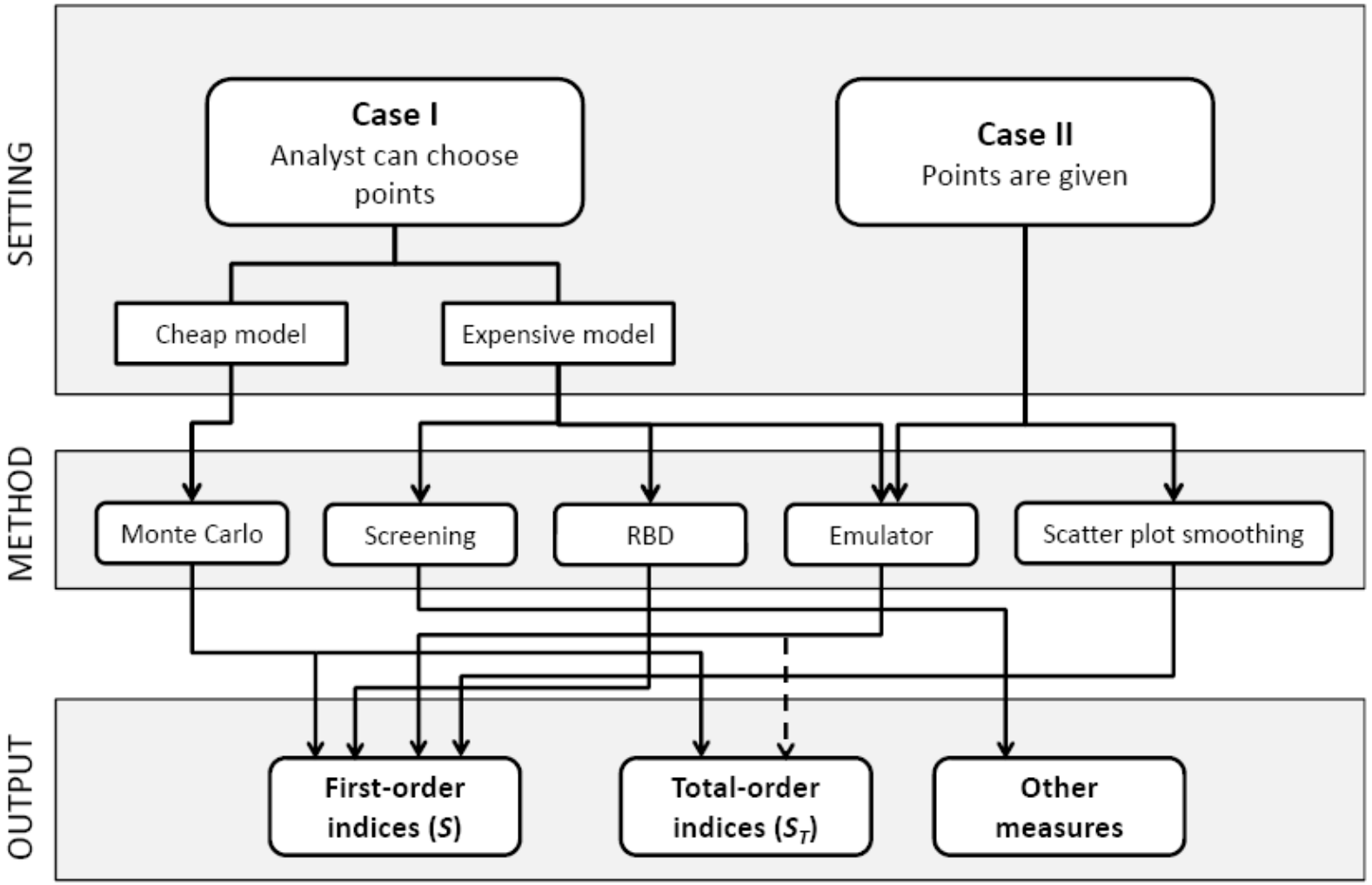


William Becker and Andrea Saltelli, 2015, Design for Sensitivity Analysis, in Handbook of Design and Analysis of Experiments, edited by Angela Dean, Max Morris, John Stufken, Derek Bingham, http://www.andreasaltelli.eu/file/repository/FINALDRAFT.pdf



[Global*] sensitivity analysis: “The study of how the uncertainty in the output of a model can be apportioned to different sources of uncertainty in the model input”

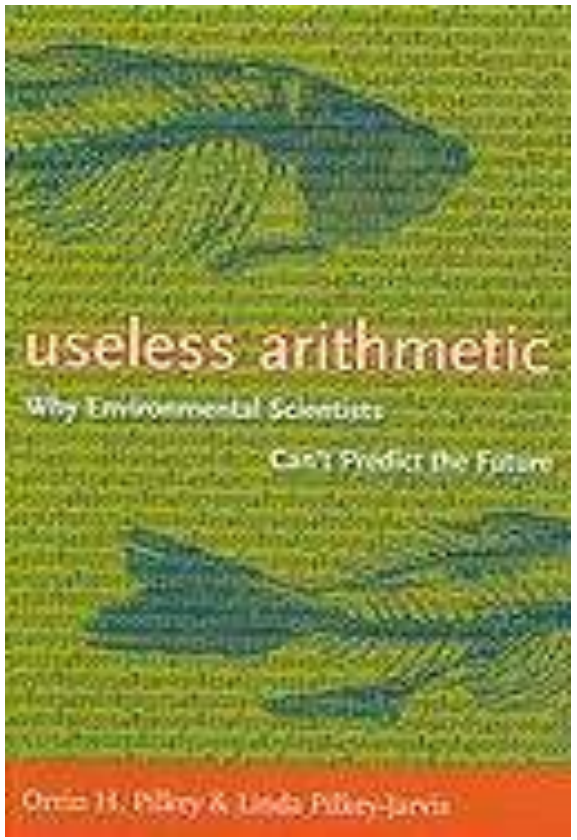
Saltelli A., 2002, Sensitivity Analysis for Importance Assessment, Risk Analysis, 22 (3), 1-12.

One can sample more than just factors (e.g. using triggers)

- Modelling assumptions
- Data bases
- Scenarios?

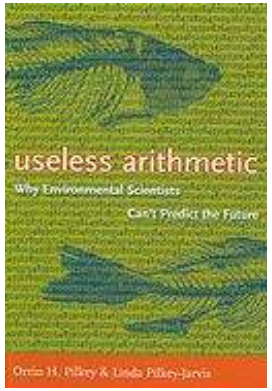
Limits of sensitivity analysis

Orrin H. Pilkey
Duke University,
NC



Useless Arithmetic: Why Environmental Scientists Can't Predict the Future

by Orrin H. Pilkey and Linda Pilkey-Jarvis

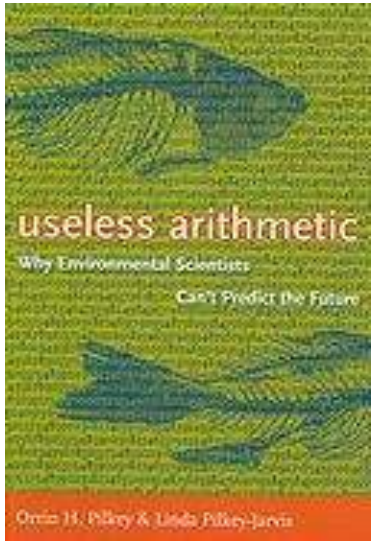


<<It is important, however, to recognize that the sensitivity of the parameter in the equation is what is being determined, not the sensitivity of the parameter in nature.

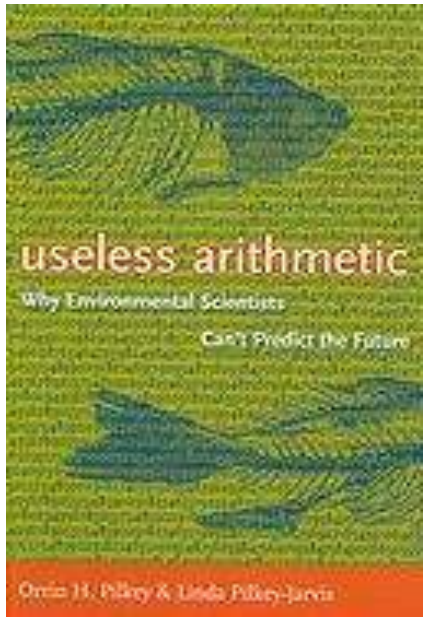
[…] If the model is wrong or if it is a poor representation of reality, determining the sensitivity of an individual parameter in the model is a meaningless pursuit.>>

Yucca Mountain repository for radioactive waste. TSPA model (for total system performance assessment) for safety analysis

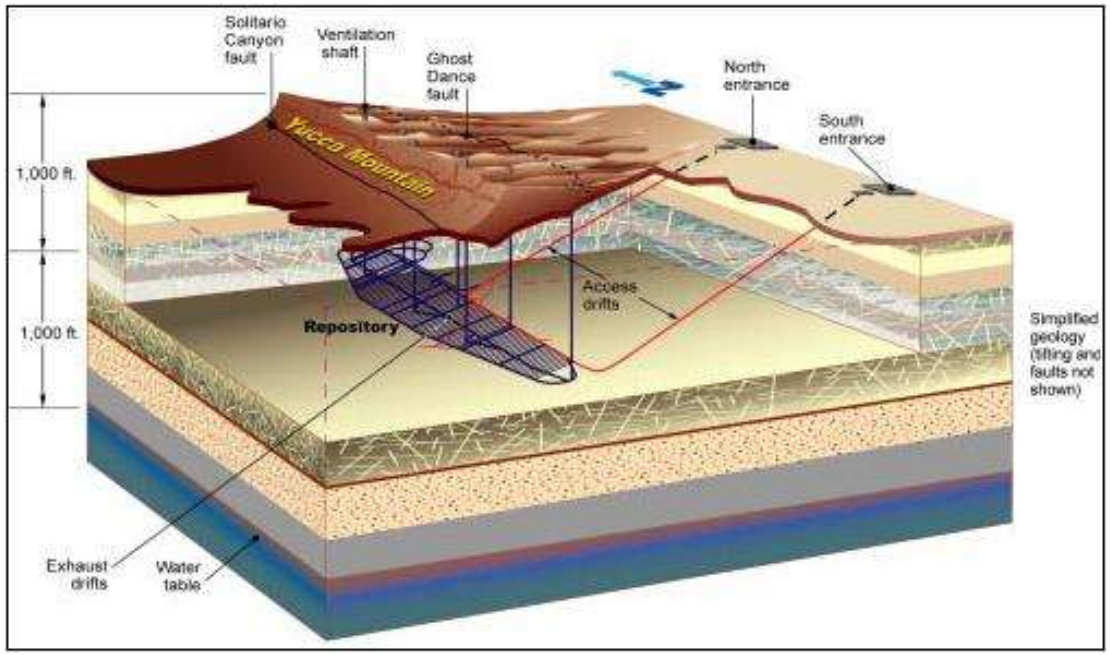
TSPA is Composed of 286 sub-models

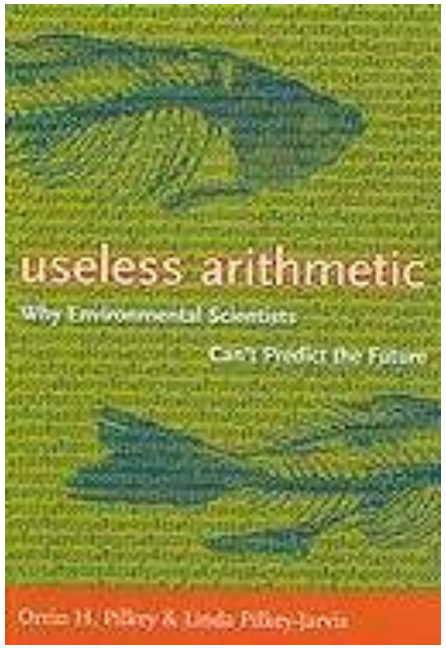


TSPA (like any other model) relies on assumptions → one is the low permeability of the geological formation → long time for the water to percolate from surface to disposal.



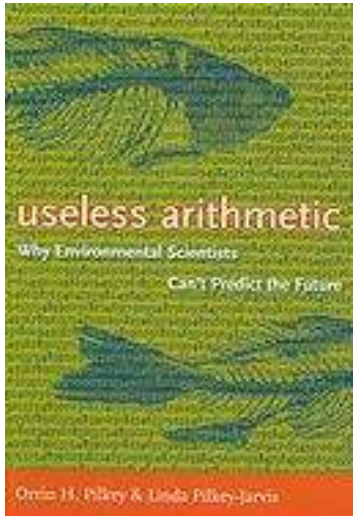
Trust in TSPA was not helped when evidence was produced which could lead to an upward revision of 4 orders of magnitude of this parameter (the ^{36}Cl story)





In the case of TSPA (Yucca mountain) a range of 0.02 to 1 millimetre per year was used for percolation of flux rate.

→… SA useless if it is instead ~ 3,000 millimetres per year.



"Scientific mathematical modelling should involve constant efforts to falsify the model"

Ref. ➔ Robert K. Merton's 'Organized skepticism '

Robert K. Merton

Communalism – the common ownership of scient40

ific discoveries, according to which scientists give up intellectual property rights in exchange for recognition and esteem (Merton actually used the term Communism, but had this notion of communalism in mind, not Marxism);

Universalism – according to which claims to truth are evaluated in terms of universal or impersonal criteria, and not on the basis of race, class, gender, religion, or nationality;

Disinterestedness – according to which scientists are rewarded for acting in ways that outwardly appear to be selfless;

Organized Skepticism – all ideas must be tested and are subject to rigorous, structured community scrutiny.

CUDOS

Communalism – the common ownership of **scientific discoveries**, according to which scientists give up intellectual property rights in exchange for recognition and esteem

Universalism – according to which **claims to truth are evaluated in terms of universal or impersonal criteria**, and not on the basis of race, class, gender, religion, or nationality;

CUDOS

Disinterestedness – according to which scientists are rewarded for acting in ways that outwardly appear to be selfless;

Organized Skepticism – all ideas must be tested and are subject to rigorous, structured community scrutiny.

Back to SA

Discussion point

The influence of the key variables
should be investigated by a sensitivity analysis.

Something wrong?
(p. 384 of EC guidelines)

$$\frac{V_{X_i}\left(E_{\mathbf{X}_{\sim i}}\left(Y|X_i\right)\right)}{V(Y)} = S_i$$

$$\frac{E_{\mathbf{X}_{\sim i}}\left(V_{X_i}\left(Y|\mathbf{X}_{\sim i}\right)\right)}{V(Y)} = S_{Ti}$$

Scaled to [0,1]; first order and total order sensitivity coefficient

Why these measures?

$$V_{X_i}\left(E_{\mathbf{X}_{\sim i}}\left(Y|X_i\right)\right)$$ Factors prioritization

$$E_{\mathbf{X}_{\sim i}}\left(V_{X_i}\left(Y|\mathbf{X}_{\sim i}\right)\right)$$ Fixing (dropping) non important factors

Saltelli A. Tarantola S., 2002, On the relative importance of input factors in mathematical models: safety assessment for nuclear waste disposal, *Journal of American Statistical Association*, **97** (459), 02-709.

More about the settings:

Factor prioritisation → $S_i \equiv \frac{V\left(E\left(Y|X_i\right)\right)}{V_Y}$

If the cost of 'discovering' factors were the same for all factors which factor should I try to discover first?

Factor fixing: Can I fix a factor [or a subset of input factors] at any given value over their range of uncertainty without reducing significantly the output?

$$S_{Ti} \equiv \frac{E\left(V\left(Y|\mathbf{X}_{\sim i}\right)\right)}{V_Y}$$

Factor fixing is useful to achieve model simplification and ‘relevance’.

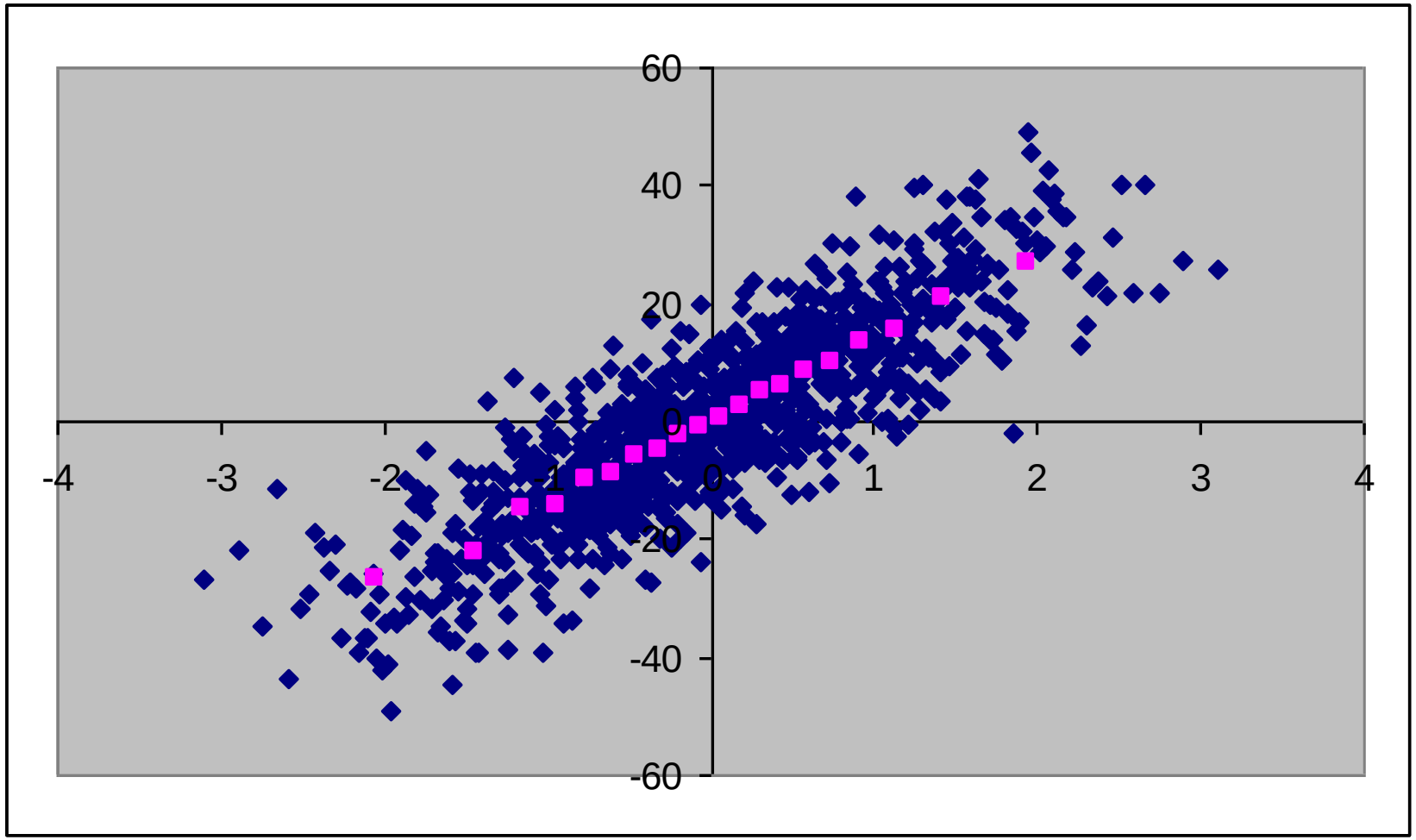
We cannot use S_i to fix a factor; S_i =0 is a necessary condition for X_i to be non-influential but not a sufficient one

X_i could be influent at the second or higher order

Summary for variance based measures:

1. Easy-to-code, Monte Carlo – better on quasi-random points. Estimate of the error available.

2. The main effect can be made cheap; its computational cost does not depend upon k.



Easy to smooth and interpolate!

Summary for variance based measures:

3. The total effect is more expensive; its computational cost is $(k+1)N$ where N is one of the order of one thousand (unless e.g. using metamodelling …).

$$A = \begin{bmatrix} a_{11} & \dots & a_{1i} & \dots & a_{1k} \\ a_{21} & \dots & a_{2i} & \dots & a_{2k} \\ \dots & \dots & \dots & \dots & \dots \\ a_{N1} & \dots & a_{Ni} & \dots & a_{Nk} \end{bmatrix}$$

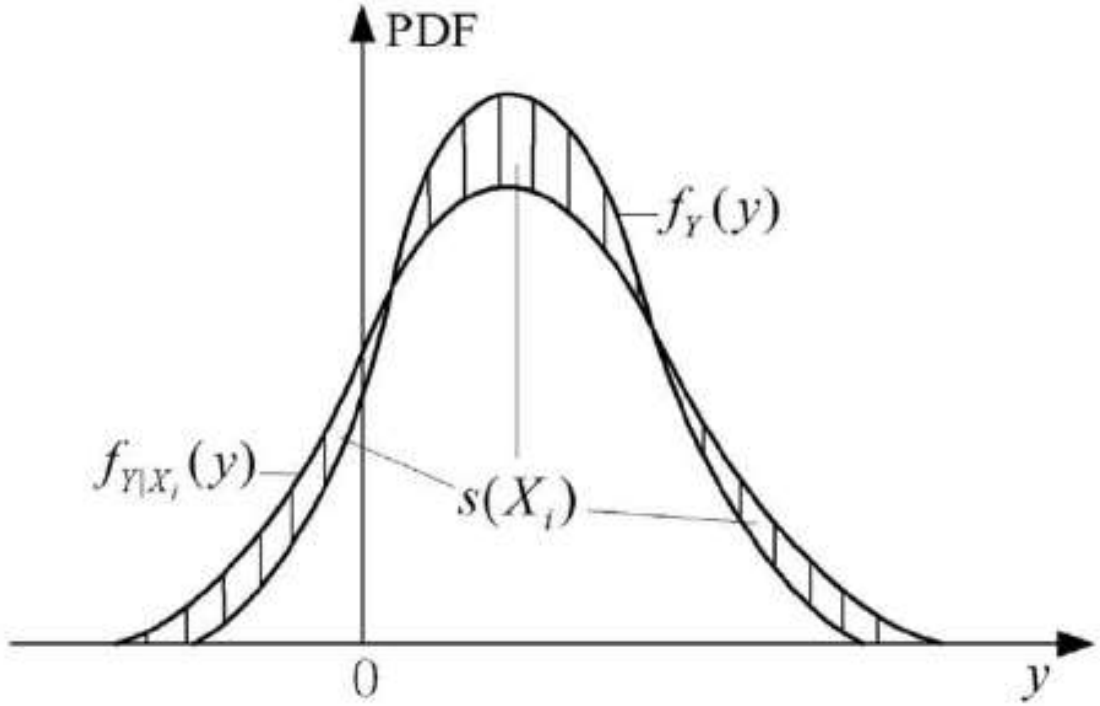
S_i

$$B_i = \begin{bmatrix} b_{11} & \dots & a_{1i} & \dots & b_{1k} \\ b_{21} & \dots & a_{2i} & \dots & b_{2k} \\ \dots & \dots & \dots & \dots & \dots \\ b_{N1} & \dots & a_{Ni} & \dots & b_{Nk} \end{bmatrix}$$

$$B = \begin{bmatrix} b_{11} & \dots & b_{1i} & \dots & b_{1k} \\ b_{21} & \dots & b_{2i} & \dots & b_{2k} \\ \dots & \dots & \dots & \dots & \dots \\ b_{N1} & \dots & b_{Ni} & \dots & b_{Nk} \end{bmatrix}$$

S_{Ti}

Other methods

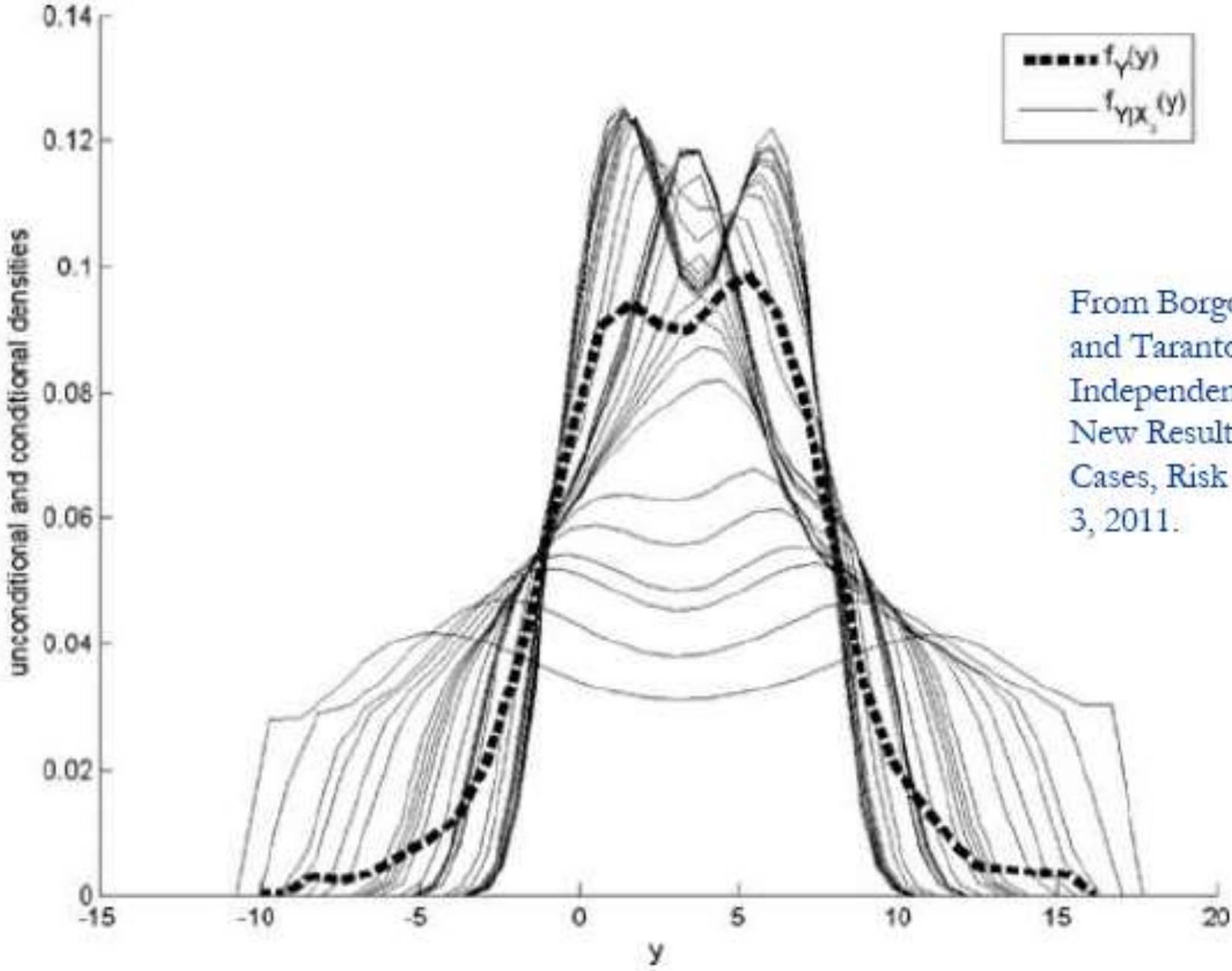


From: Leigang Zhang, Zhenzhou Lu , Lei Cheng, Chongqing Fan, A new method for evaluating Borgonovo moment-independent importance measure …, Reliability Engineering and System Safety 132 (2014) 163–175.

$$s(X_i) = \int_{-\infty}^{+\infty} |f_Y(y) - f_{Y|X_i}(y)| \, dy$$

$$E_{X_i}[s(X_i)] = \int_{-\infty}^{+\infty} f_{X_i}(x_i) s(X_i) dx_i$$

$$\delta_i = \frac{1}{2} E_{X_i}[s(X_i)]$$

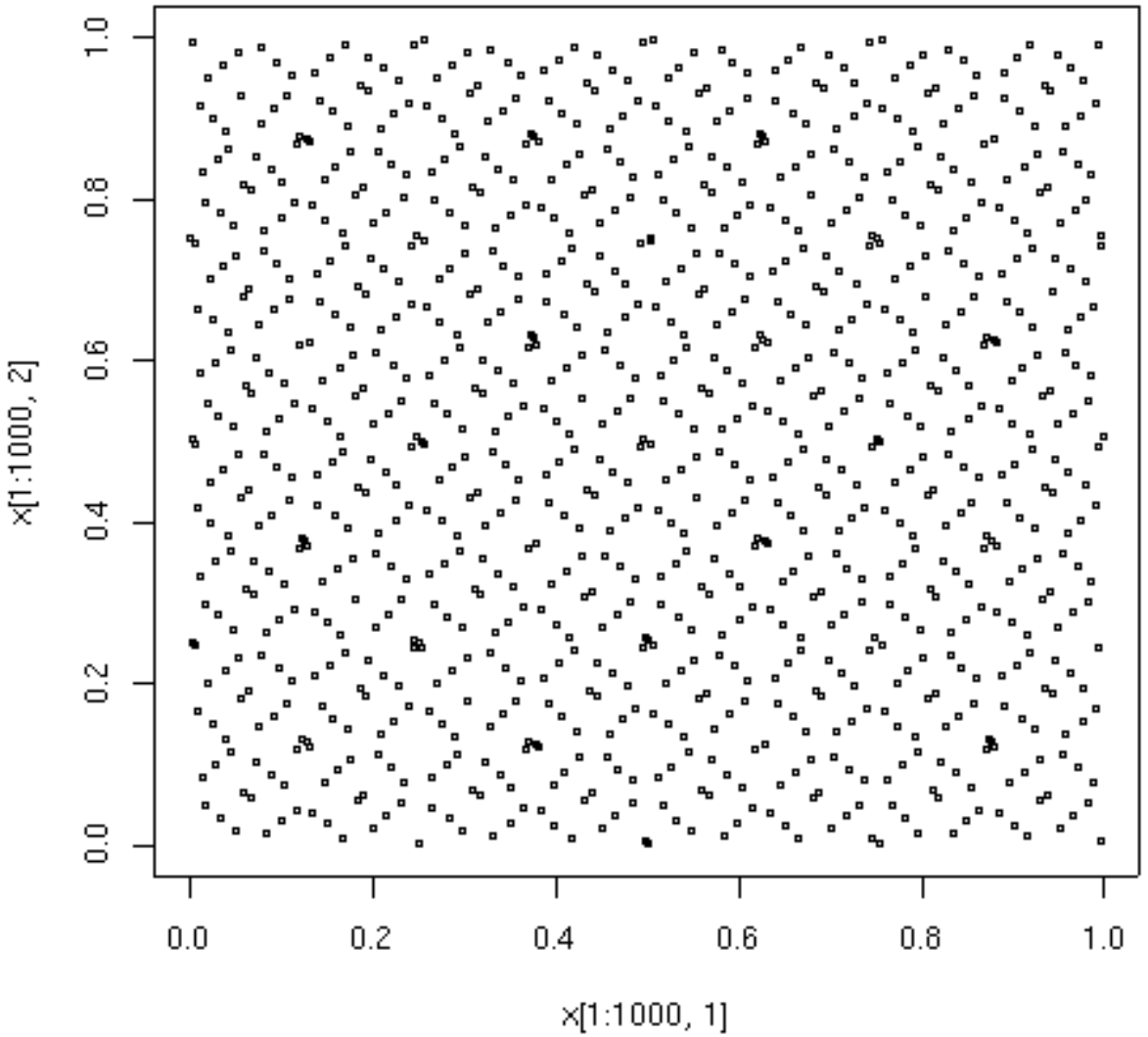


From Borgonovo, E., Castaings, W. and Tarantola, S., Moment Independent Importance Measures: New Results, and Analytical Test Cases, Risk Analysis, Vol. 31, No. 3, 2011.

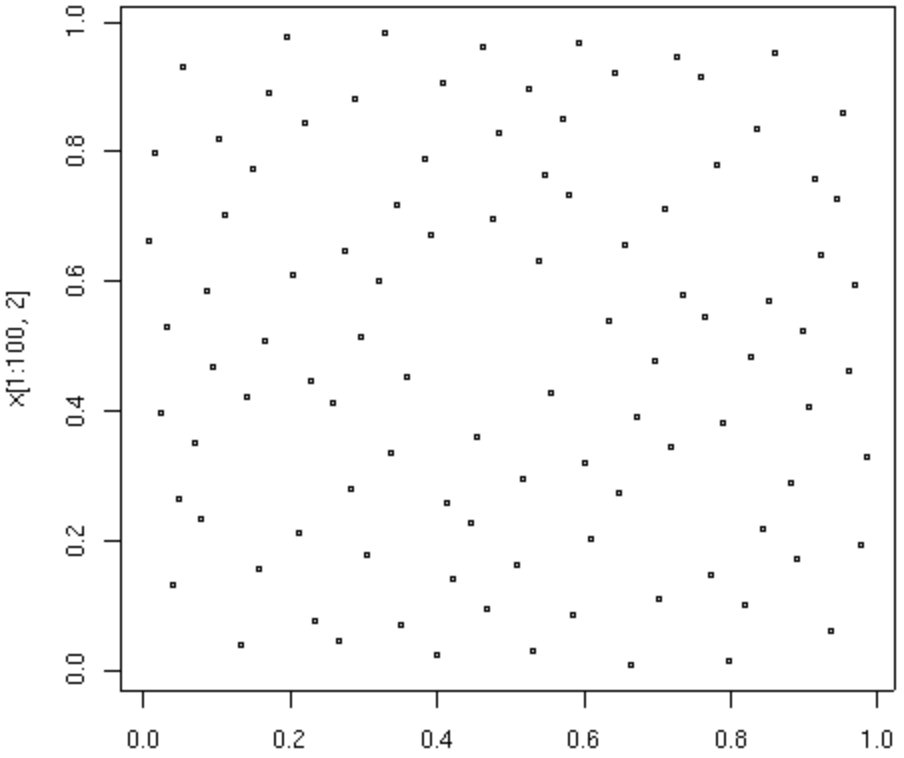
Try quasi random sequences!

Sobol' LP_τ sequences

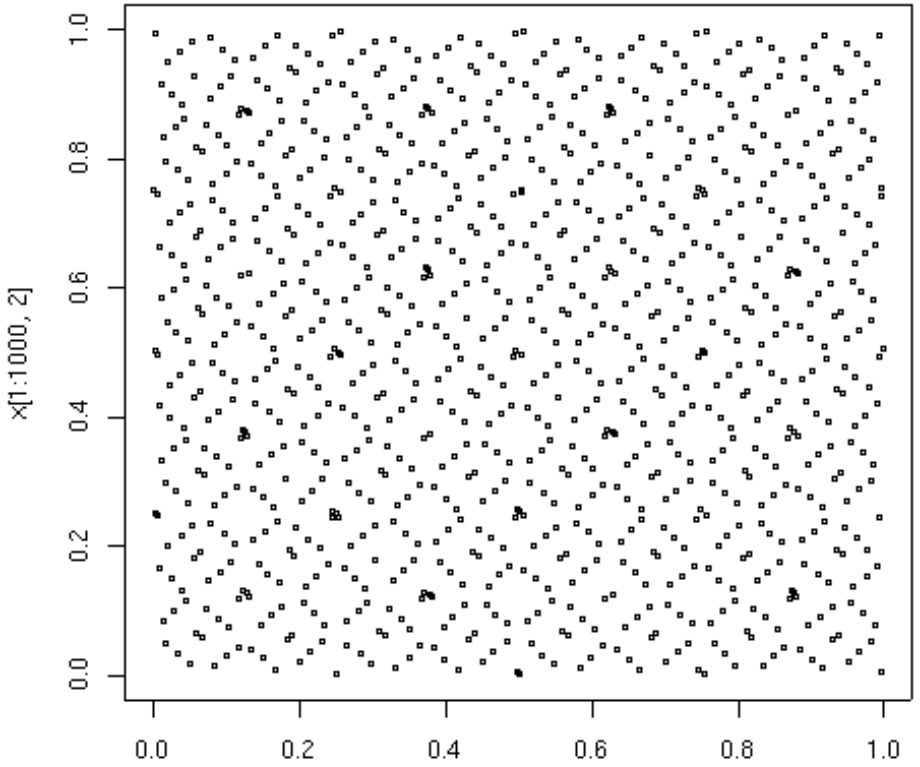
(Scrambled)



An LP_τ sequence

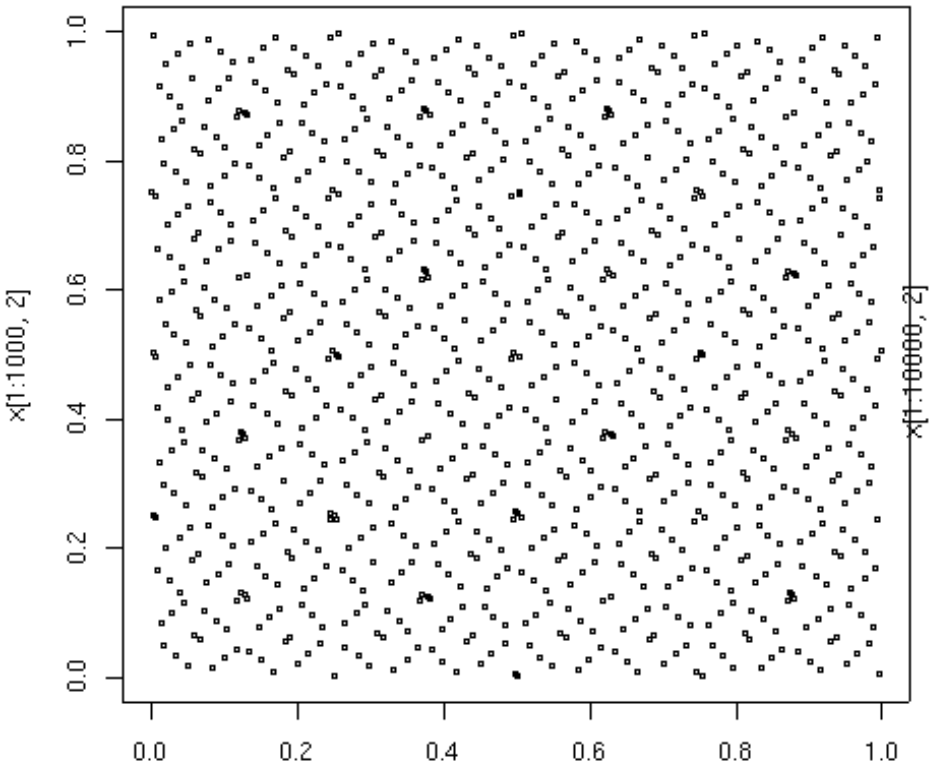


X1,X2 plane, 100 Sobol' points

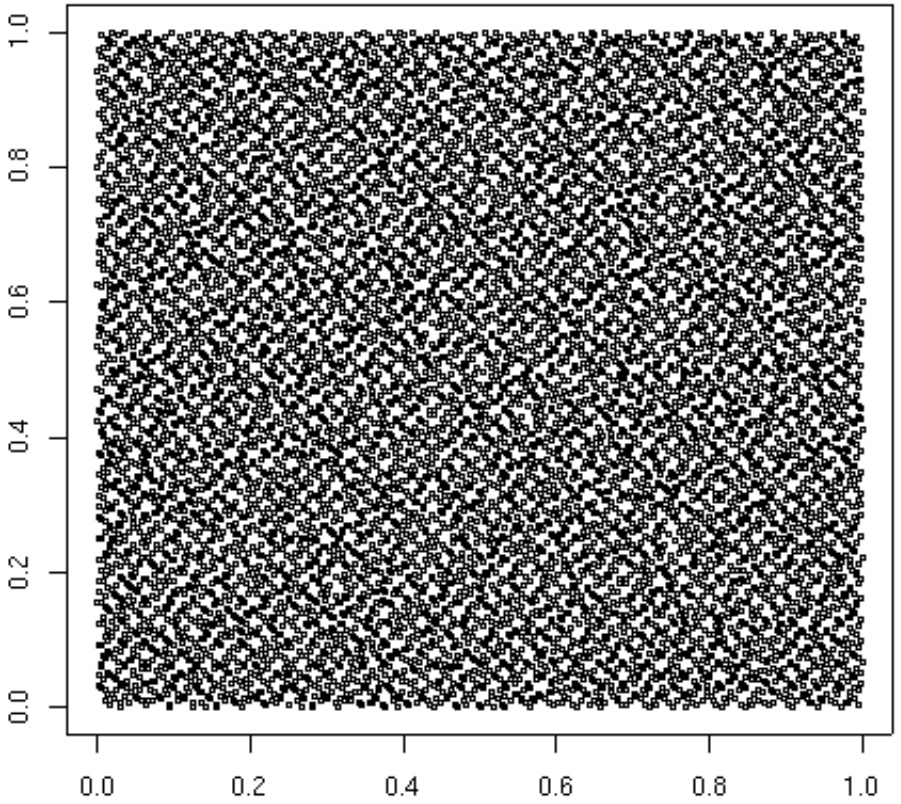


X1,X2 plane, 1000 Sobol' points

Sobol' sequences of quasi-random points

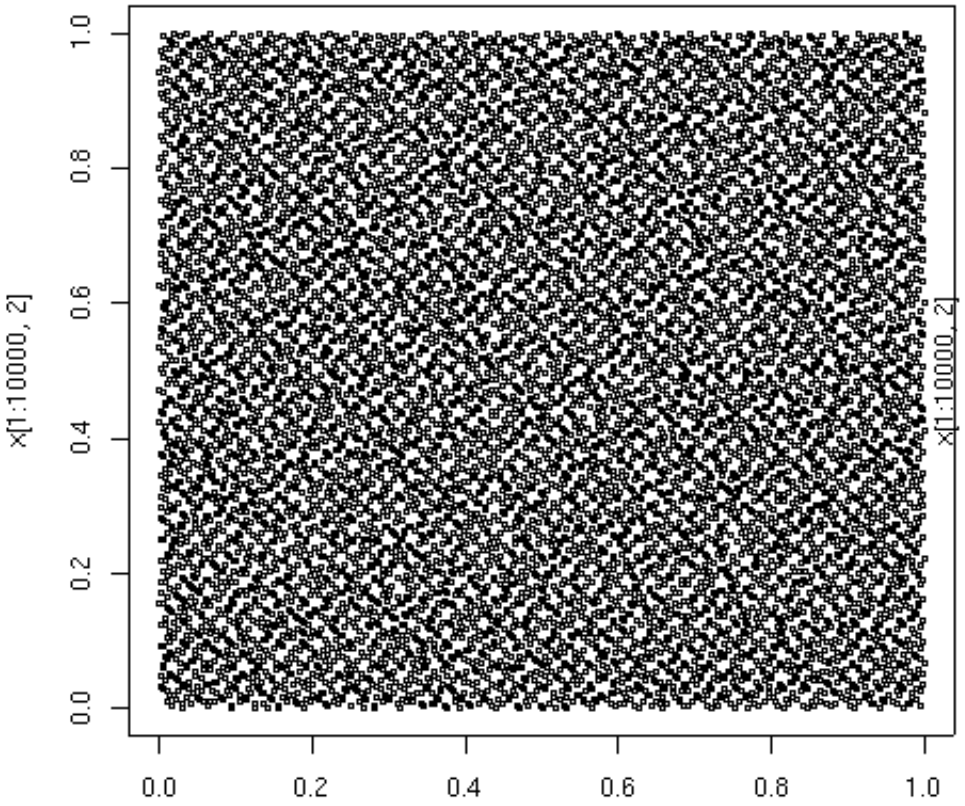


X1,X2 plane, 1000 Sobol' points

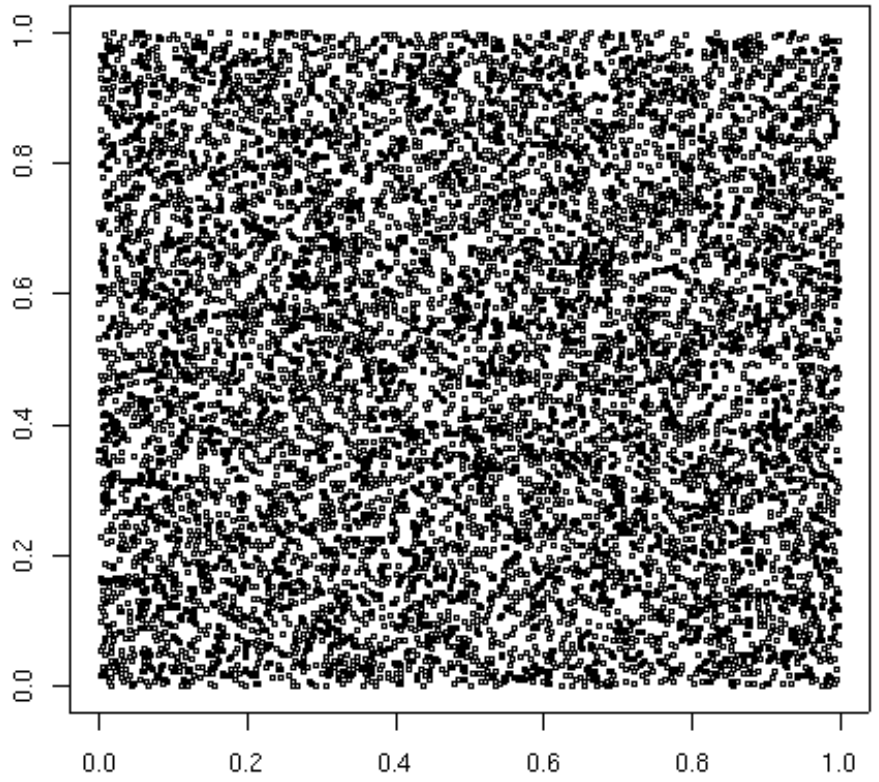


X1,X2 plane, 10000 Sobol' points

Sobol' sequences of quasi-random points



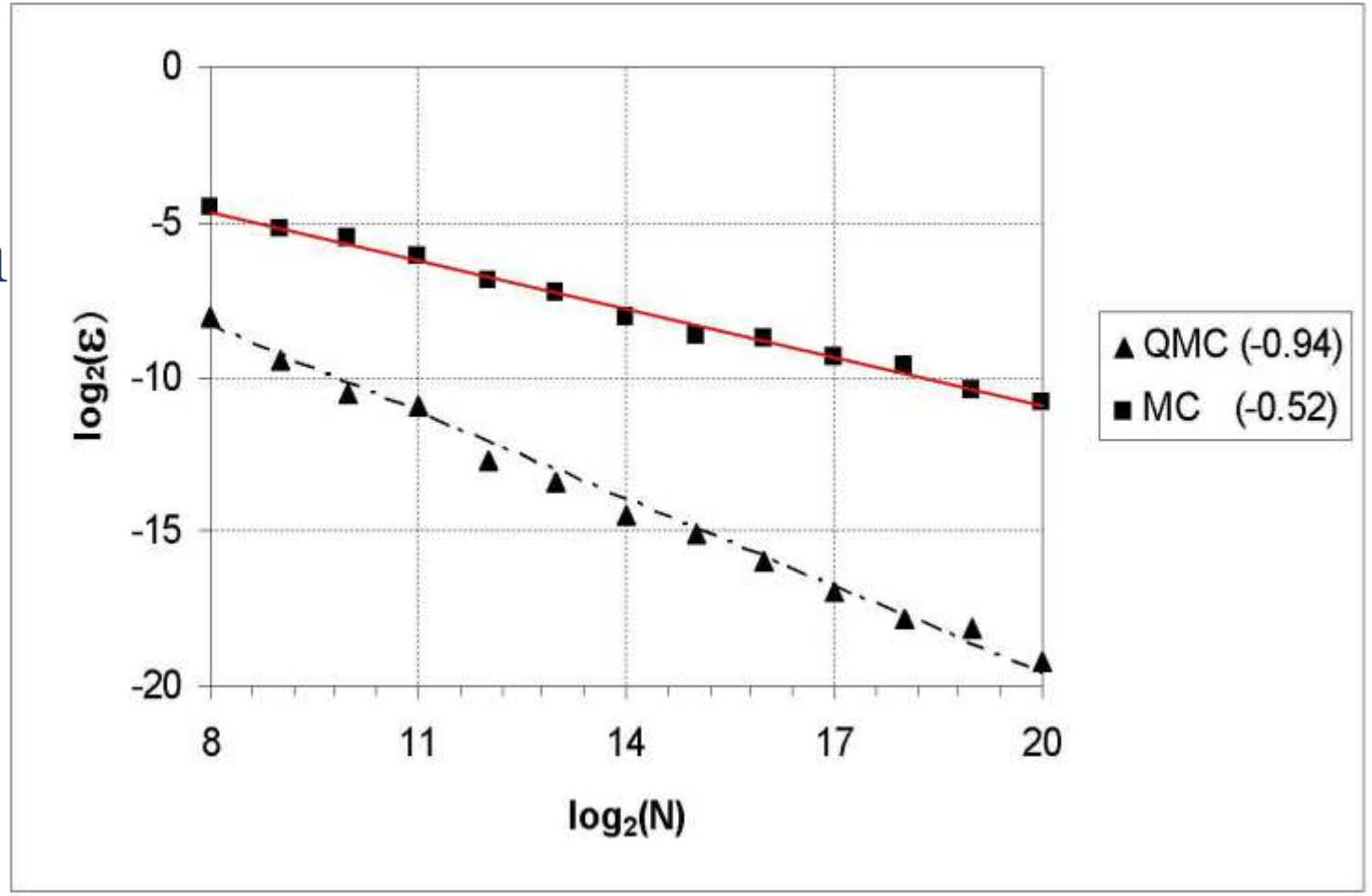
X1,X2 plane, 10000 Sobol' points



X1,X2 plane, 10000 random points

Sobol' sequences of quasi-random points against random points

Why quasi-random



Sergei Kucherenko

$$\varepsilon = \left(\frac{1}{K} \sum_{k=1}^{K} (I[f] - I_k[f])^2 \right)^{1/2}$$

$$\sum_{i=1}^{n} (-1)^i \prod_{j=1}^{i} x_j$$

Root mean square error over K=50 different trials. The error refers to the numeric-versus-analytic value the integral of the function (for n=360) over its dominion.

Source: Kucherenko S., Feil B., Shah N., Mauntz W. The identification of model effective dimensions using global sensitivity analysis Reliability Engineering and System Safety 96 (2011) 440–449.

Variance based measures are:
-well scaled,
-concise,
-easy to communicate.

Further
- S_i equals Pearson's η^2 and reduces to squared standard regression coefficients β^2 for linear model.
- S_{Ti} detect and describe interactions and becomes a screening test at low sample size (better than Morris)

See Campolongo F, Saltelli A, Cariboni, J, 2011, From screening to quantitative sensitivity analysis. A unified approach, *Computer Physics Communication*, 182 (4), pp. 978-988.

Black list of practices

Don’t throw many SA methods to a problem; justify your choice

Will your client make sense of your work?

Nullius in verba / Take nobody's word

Trust recipes up to a point

Make your own experiments

Build your Monte Carlo computing environment carefully, with an eye to its future use

Don’t try it straight away on your ‘big’ model!

Training "Numbers for Policy", Barcelona
August 27th – September 1st

http://www.uib.no/en/svt/115575/numbers-policy-practical-problems-quantification

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END

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