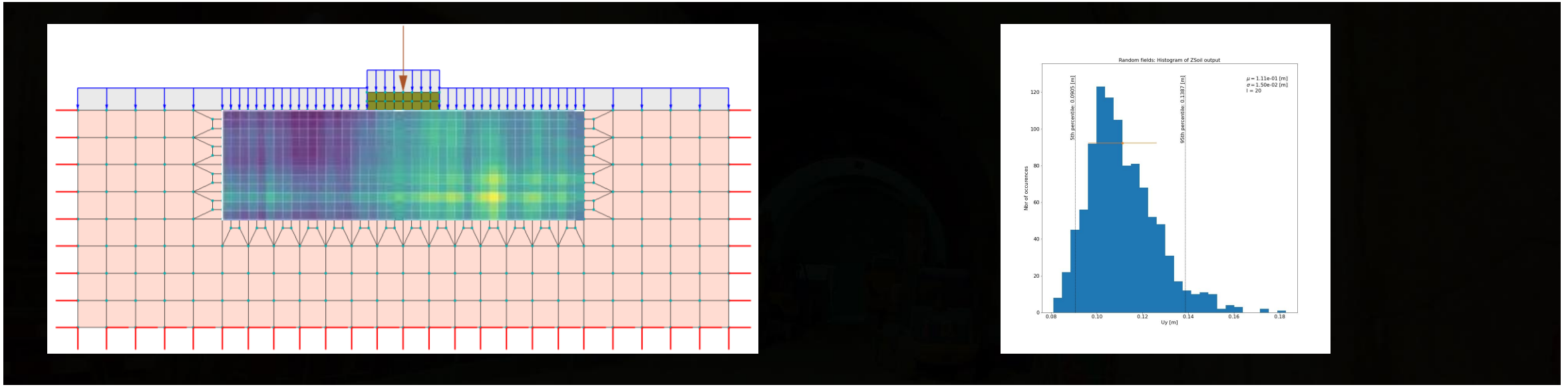
Random fields in geotechnics with ZSOIL.PC & UQLab

Marc Groslambert and Gil Jacot-Descombes GeoMod SA

August 2021



Outline

- Presentation of random fields
- Example of random field analysis
    - presentation of the case
    - implementation
    - Monte Carlo reliability
- Future developments

1- What is a random field ?

Definition

A random field $H(\mathbf{x})$ is defined as a collection of random variables indexed by a continuous parameter $x \in \mathbb{R}^2$

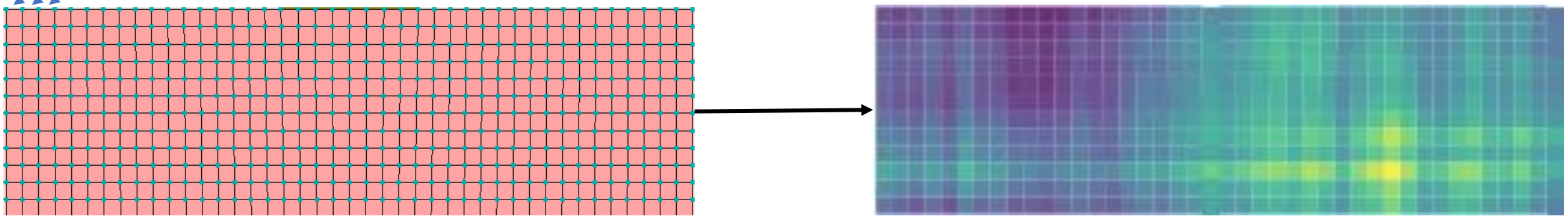
Property

A Gaussian RF is entirely defined by its mean $\mu(\mathbf{x})$, variance $\sigma^2(\mathbf{x})$ and autocorrelation function $\rho(\mathbf{x}, \mathbf{x}')$.

1- What is a random field ?

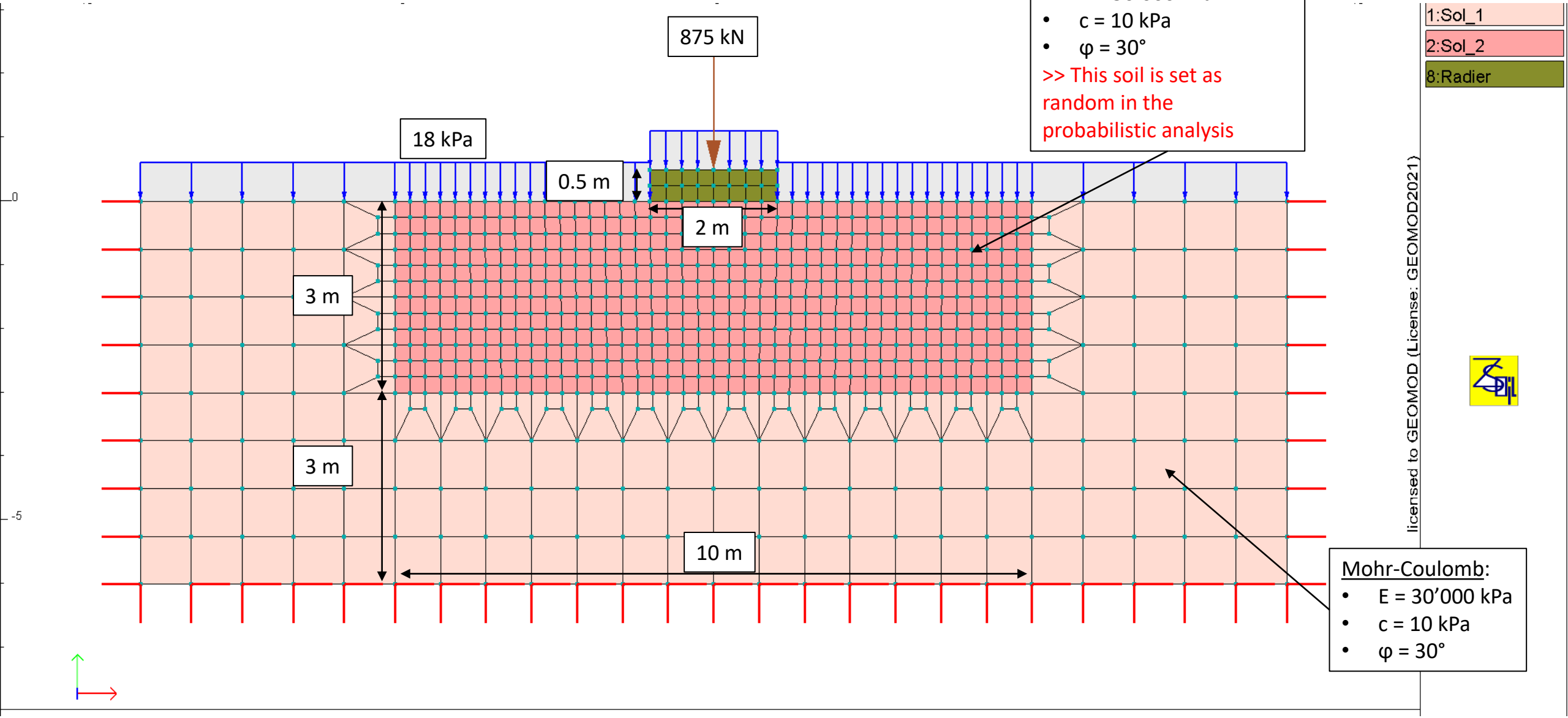
To apply RF to FE models : discretization with midpoint method, EOLE, or Karhunen-Loeve expansion.

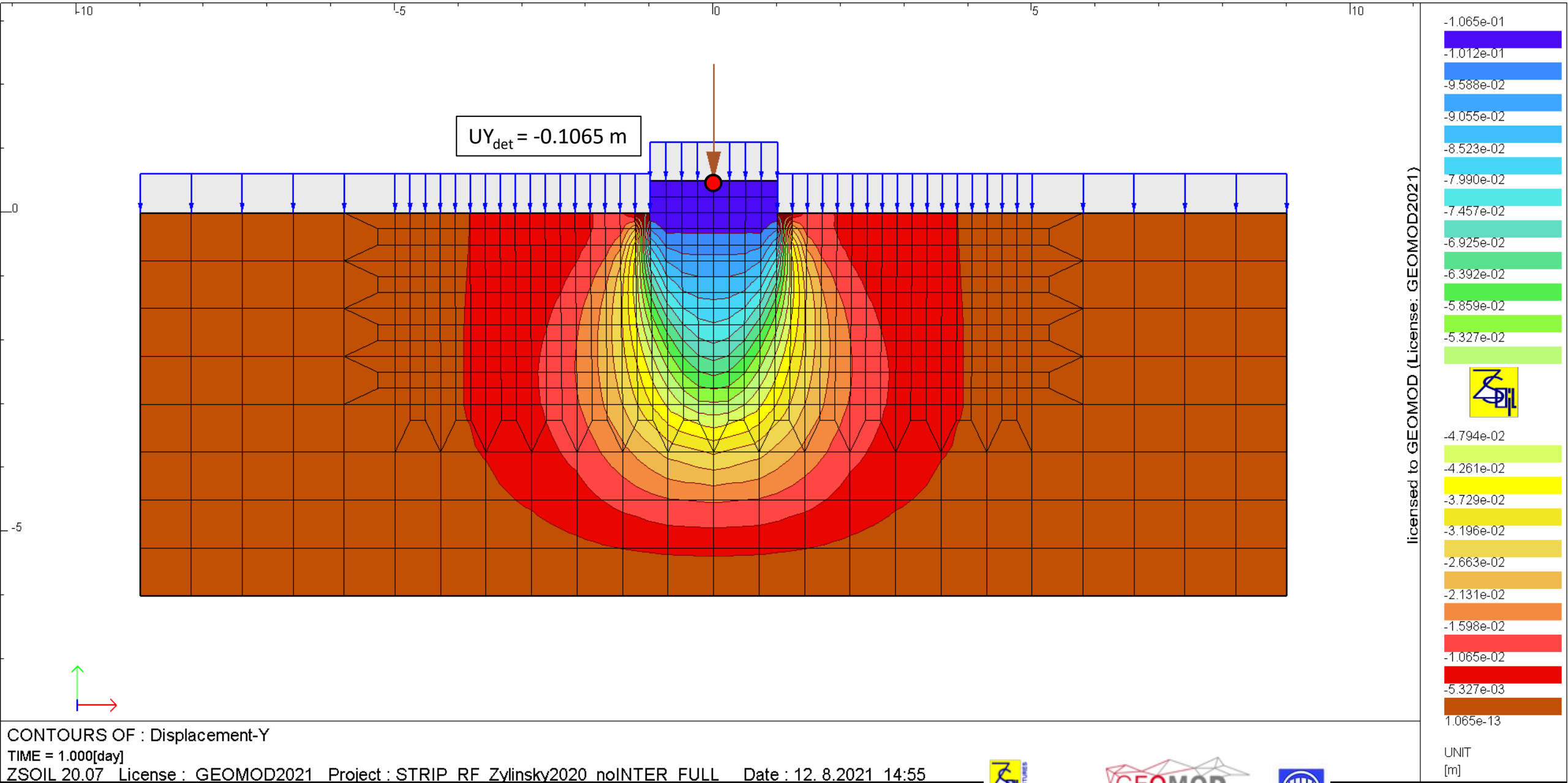
Midpoint method : sample of H, in the middle of the element
No approximation, but time expensive in high dimension ->
dimension reduction methods available



An exemple of sample

Example taken from Zylinski [2020]





CONTOURS OF : Displacement-Y

TIME = 1.000[day]

ZSOIL 20.07 License : GEOMOD2021 Project : STRIP_RF_Zylinsky2020_noINTER_FULL Date : 12. 8.2021 14:55

Random fields: They are used to model spatial variability of continuum media. They are completely described by a mean **μ**, a standard deviation **σ** and an autocorrelation coefficient function **ρ(l)**, where l is the autocorrelation length.
In the present example the Young's modulus E of the second soil is modeled as a lognormal random field and its parameters are:

$\mu = 50$ MPa

$\sigma = 15$ MPa

$$\rho = \exp\left(-\frac{|x|}{l} - \frac{|y|}{l}\right)$$

LIVE : implementation of the analysis with the interface

Interface ZSoil - UQ[py]Lab

OPEN | LOAD | RUN | PLOT | ANALYSE | QUANTITY | SETTINGS

Materials parameters

Sol_1: E_{50} = 30000 kPa, φ = 30 °, c = 10 kPa

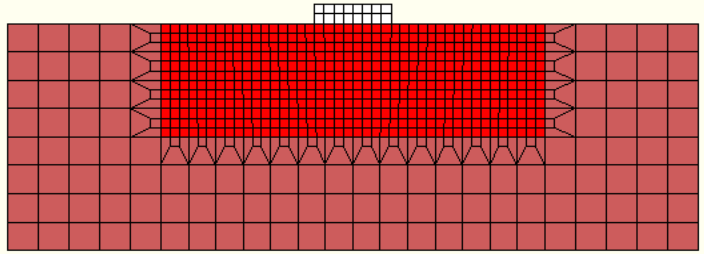
Sol_2: E_{50} = 50000.0 kPa, (+/-30.0 %) φ = 30 °, c = 10 kPa

Existence functions

Load functions

No Name:

Scale factor : 1



Limit State: U_y> 0.01

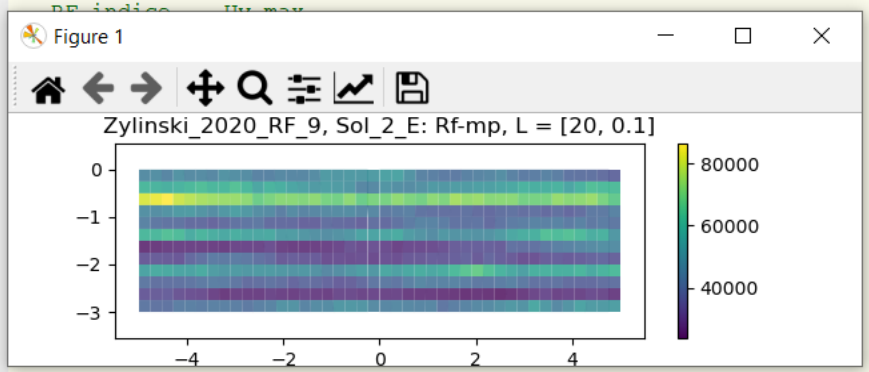
Number of samples (for PDF and Sobol) : 10

- (•) Sampling for PDF
- ( ) Reliability Analysis
- ( ) Sobol Analysis

Quantity of interest : U_y_max among all times and nodes

☐ Export Results to CSV

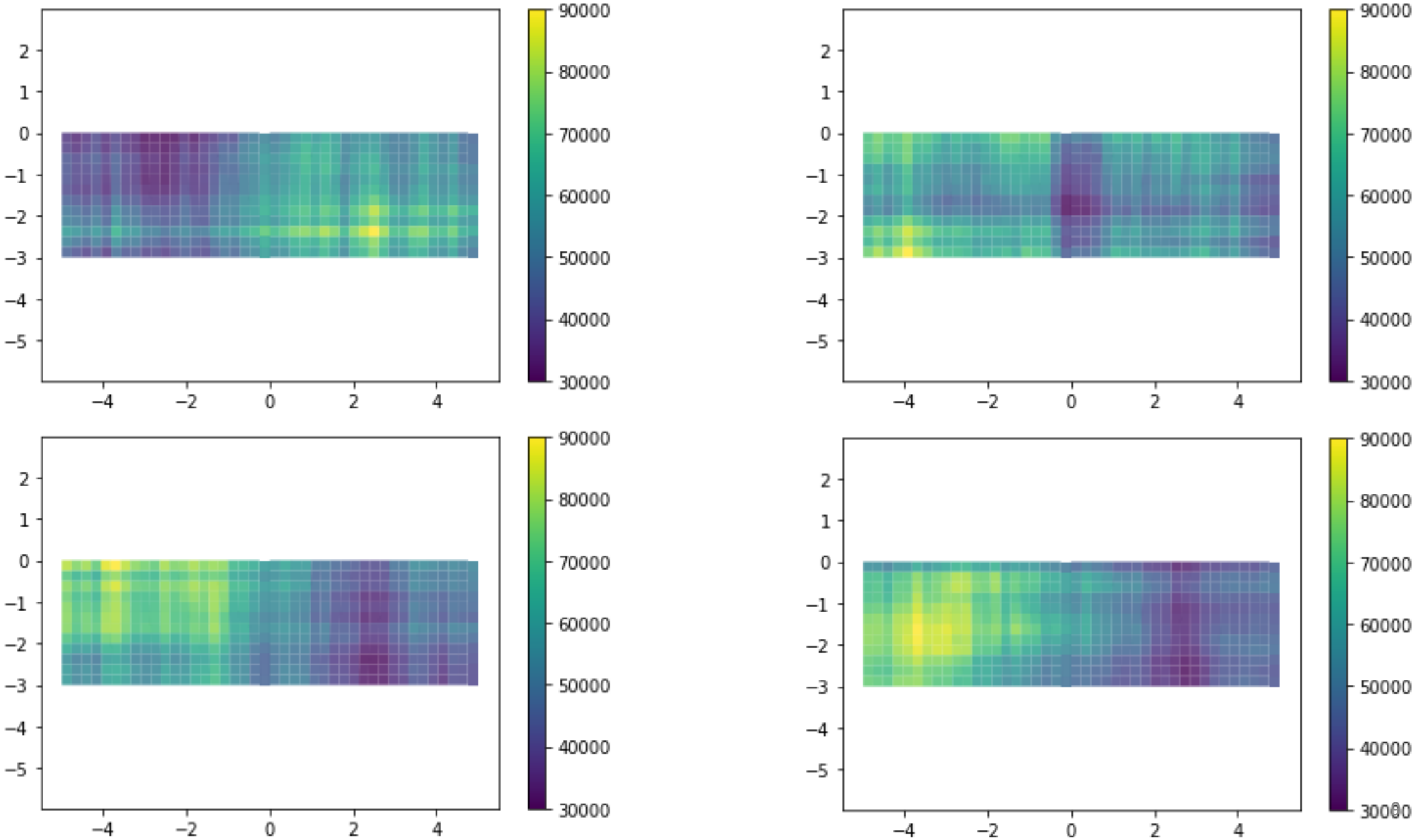
```
> Y
Analysis running...
30-08-21 09:56:35: Running Zylinski_2020_RF.inp, 0



Done.
```



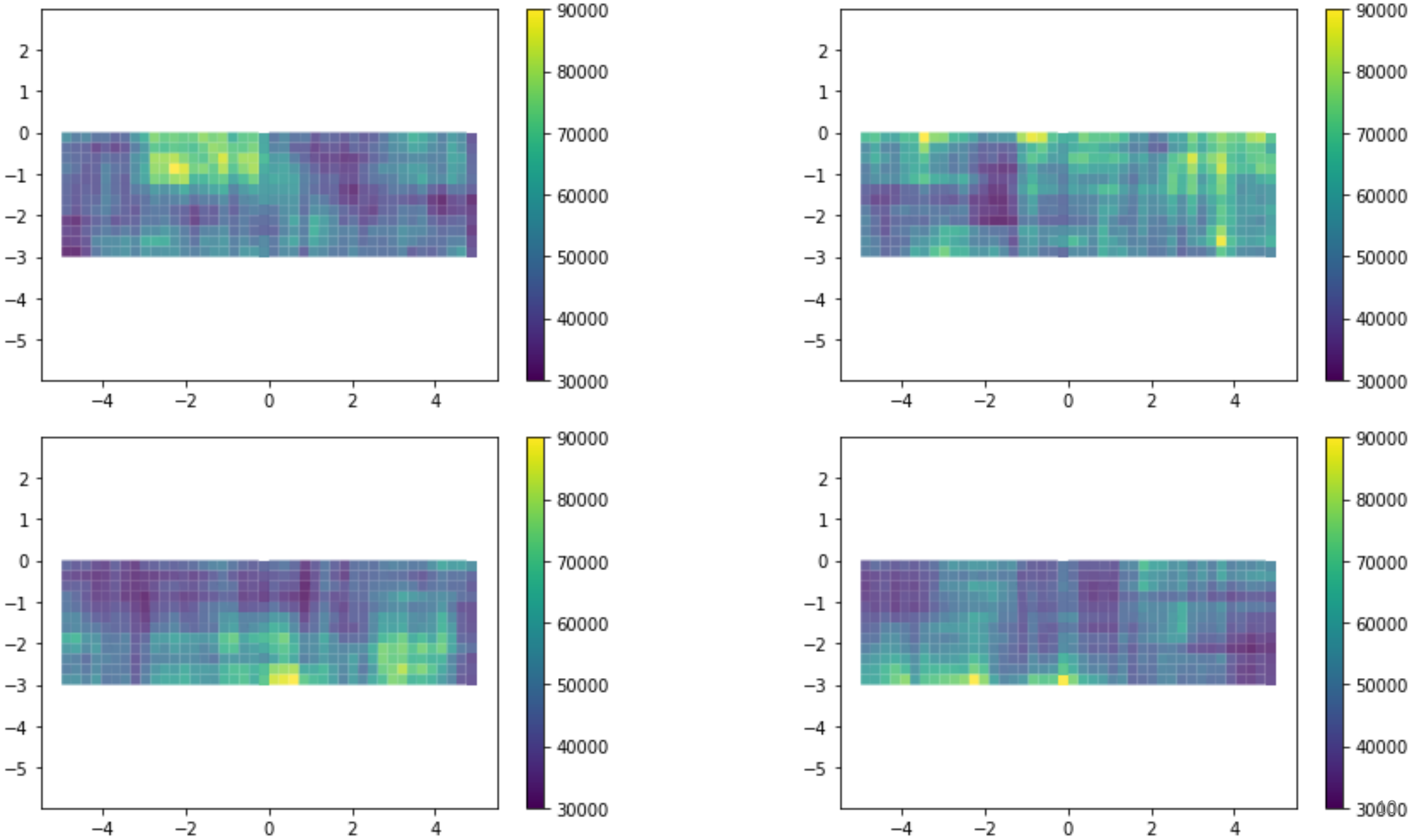

```
Pf = 1.0

Please enter the number of the RF you want to plot :
> 9

   RF indice    Uy,max
------------  --------
           0  0.117341
           1  0.101604
           2  0.105362
           3  0.105816
           4  0.109531
           5  0.109739
           6  0.11023
           7  0.117741
           8  0.108931
           9  0.11589

%------Probability of failure Pf------%

Pf = 1.0

Plot done, value of output : 0.11589
```

Next

Some random field realizations with l = 20 m

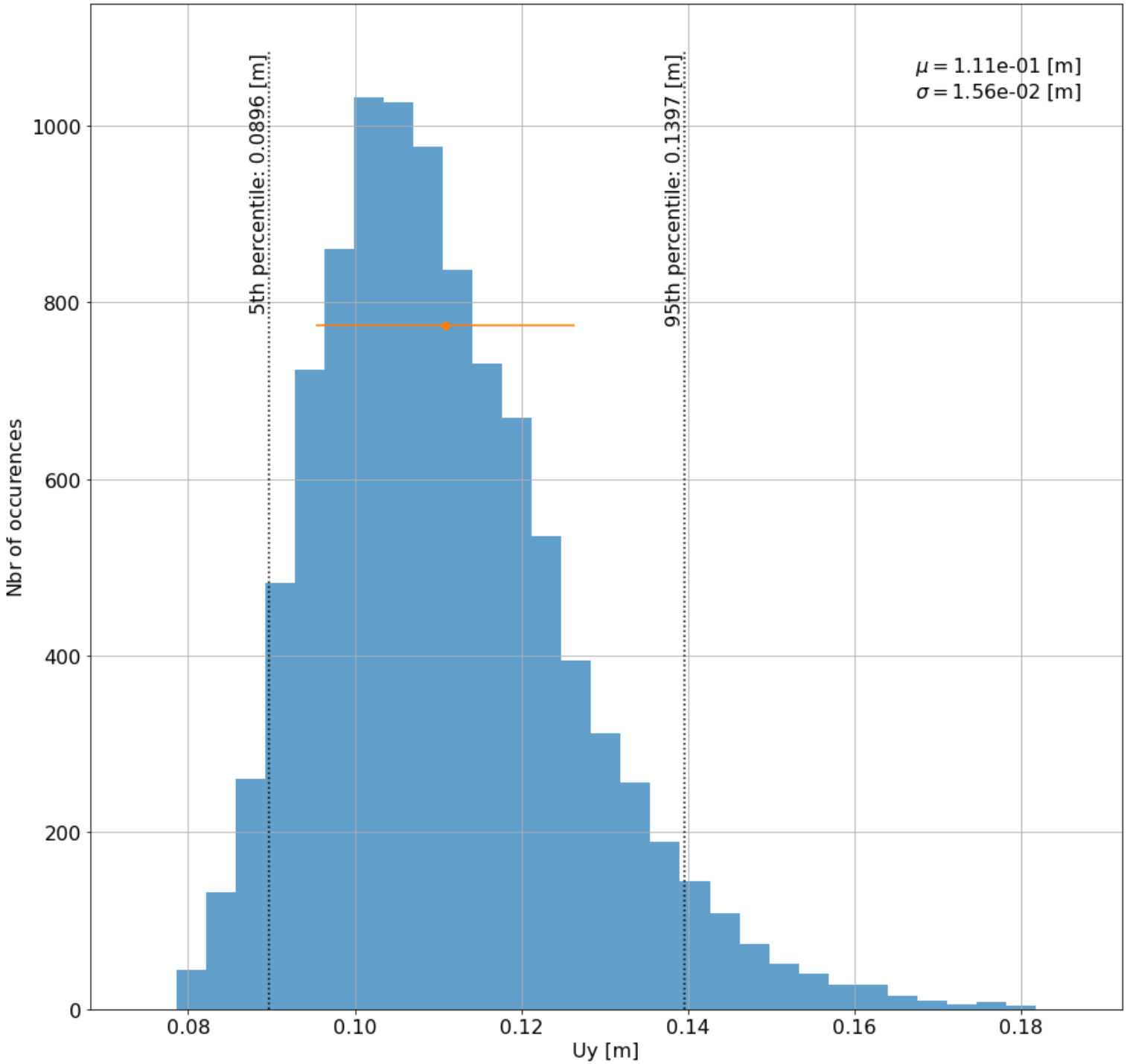


Some random field realizations with l = 2 m



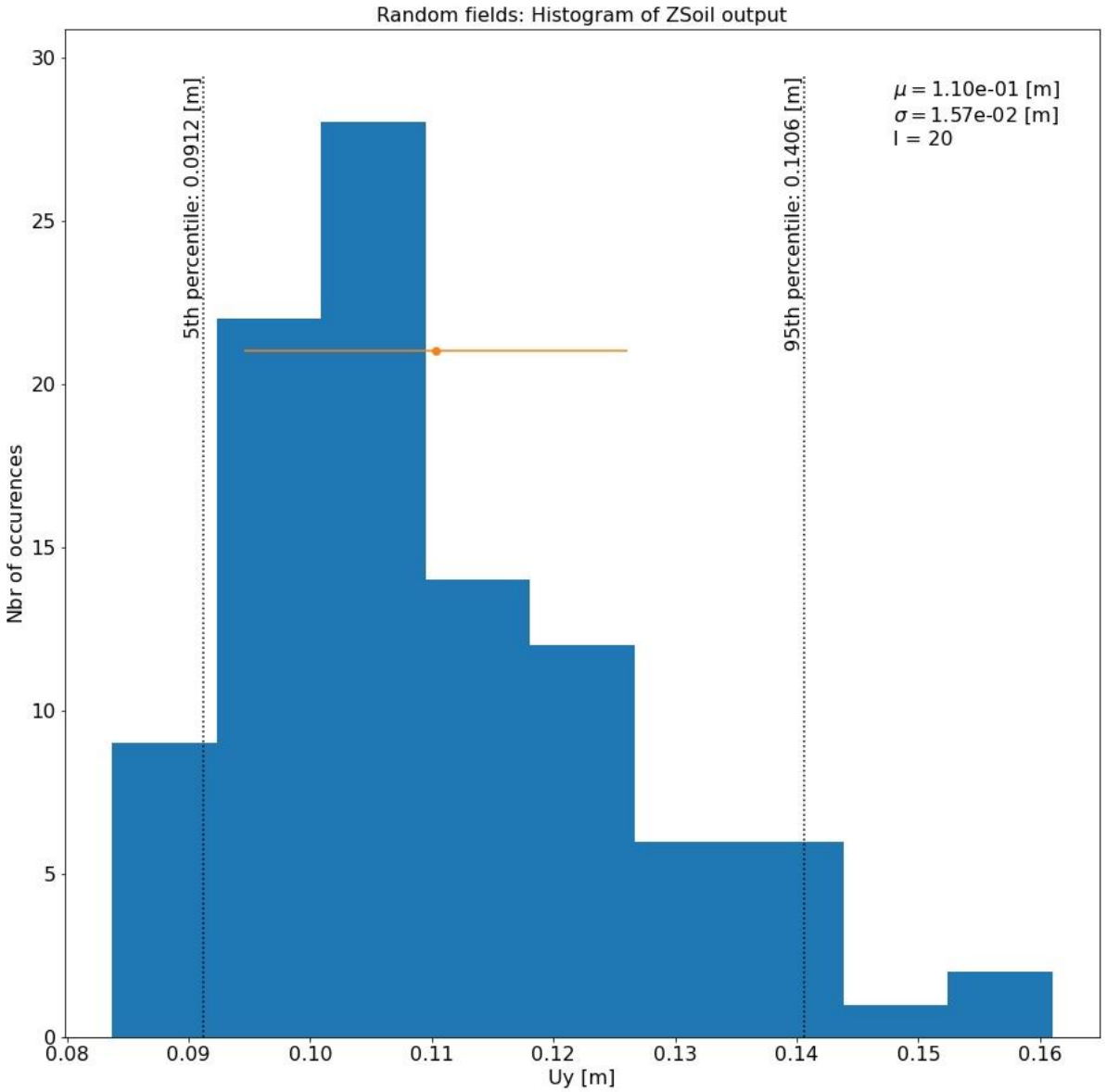
Without random fields:

- E = LN(50 MPa, 15 MPa)
- 10’000 runs of a PCE built on 50 ZSoil realizations



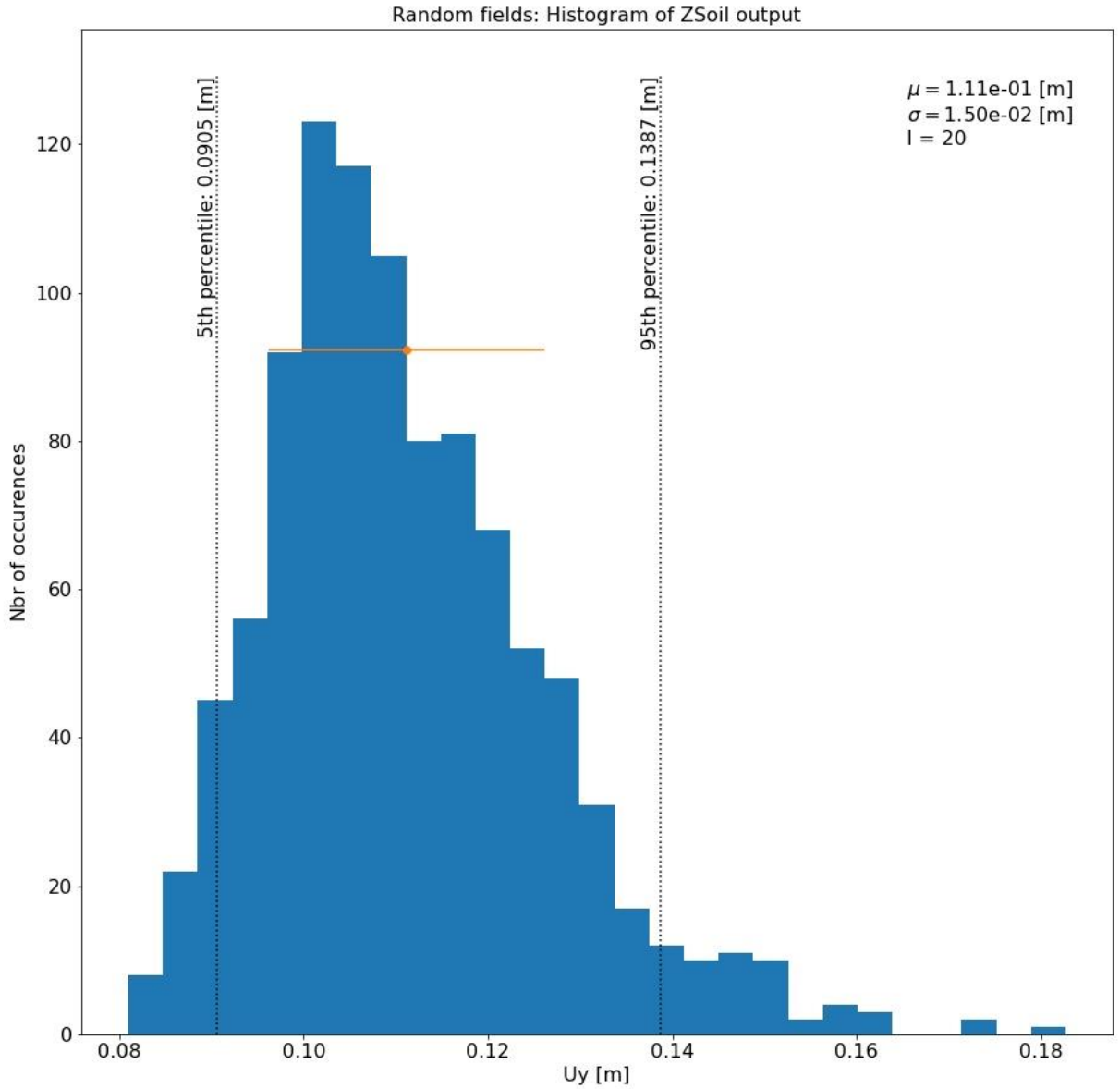
With random fields:

- Correlation length l = 20 m
- 100 realizations



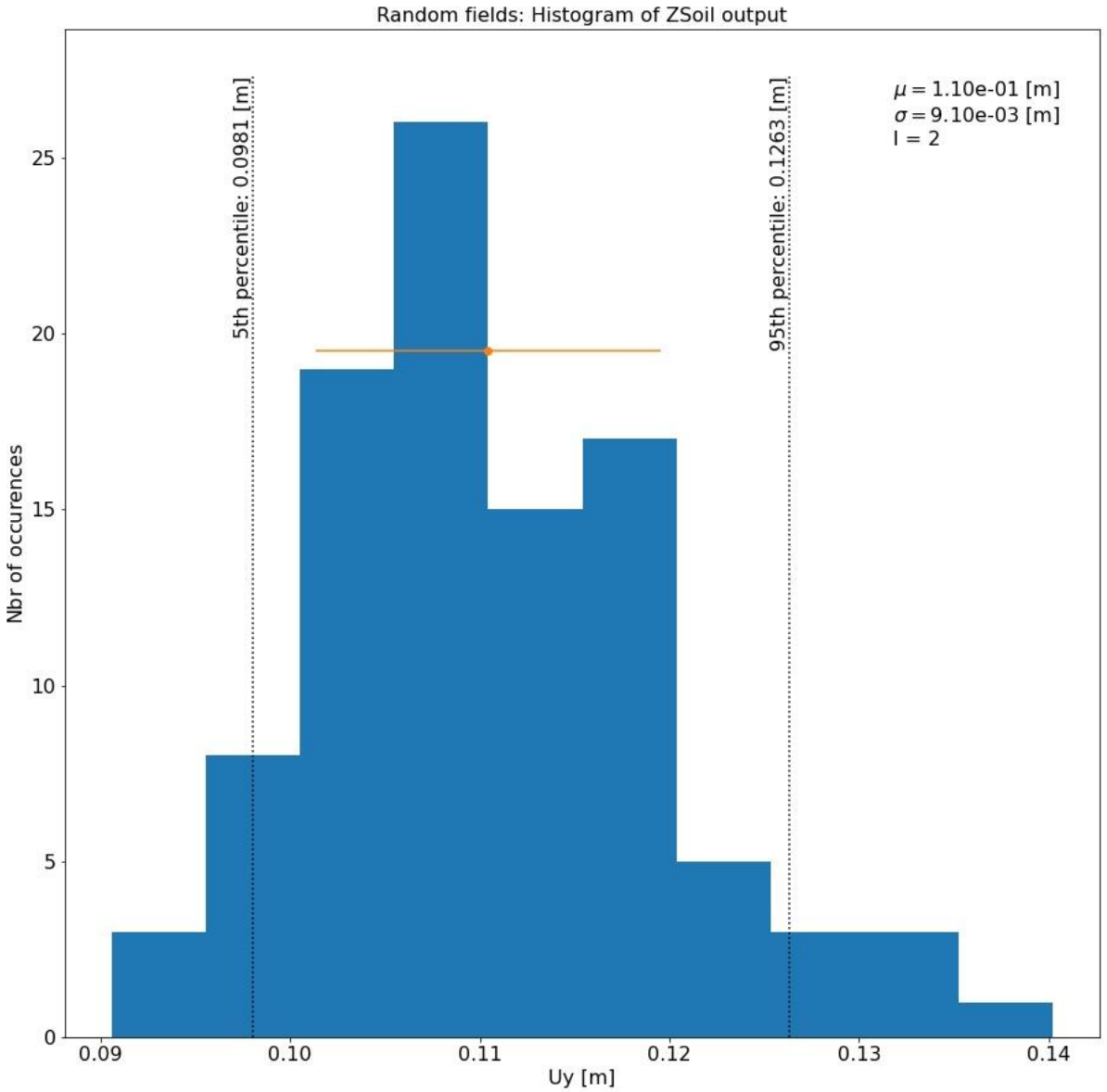
With random fields:

- Correlation length l = 20 m
- 1000 realizations



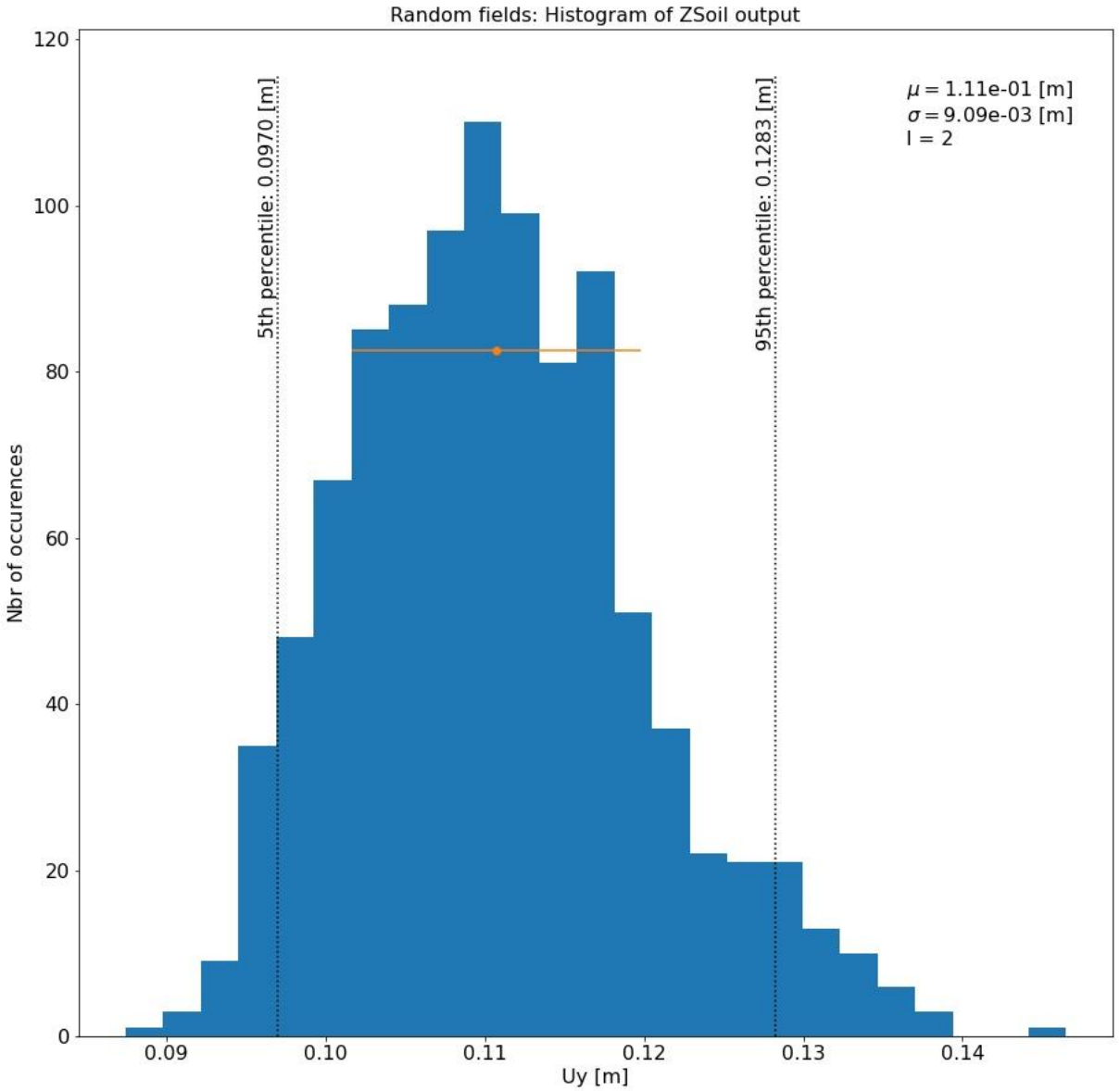
With random fields:

- Correlation length l = 2 m
- 100 realizations



With random fields:

- Correlation length l = 2 m
- 1000 realizations



Comparison of the probability of failure for different analyses:

- Failure criterion UY > 0.14 m
- P_f = P(UY > 0.14 m), with Monte Carlo

n	l	P_f
100	20 m	0.080
1’000	20 m	0.046
100	2 m	0.010
1’000	2 m	0.001
50 + 10’000	-	0.049

3- Pros and cons

- Allows to take into account spatial variability -> realistic method

- Main drawback : you need to know the correlation length in the material

- The results towards the probability of failure are really problem dependant : it is sometime reduced compared to a UQ analysis, but not always.

<u>What's next ?</u>

- Development of the interface
- Use UQLab PCE on the random fields : tests have been done, but it's not fully operational : for Sobol, accurate reliability, maybe Bayesian analysis
- Try to draw conclusions on the trends on the probability of failure, on well known cases (excavations, foundations etc…)

- THANK YOU FOR YOUR ATTENTION…

- QUESTIONS?

Acknowledgements

- Prof. Th. Zimmermann, Zace Ltd.
- Prof. Sudret, Dr Marelli, ETHZ
- My colleagues @GeoMod