KIVI Geotechniek webinar

24 June 2021

Modelling of geotechnical uncertainty

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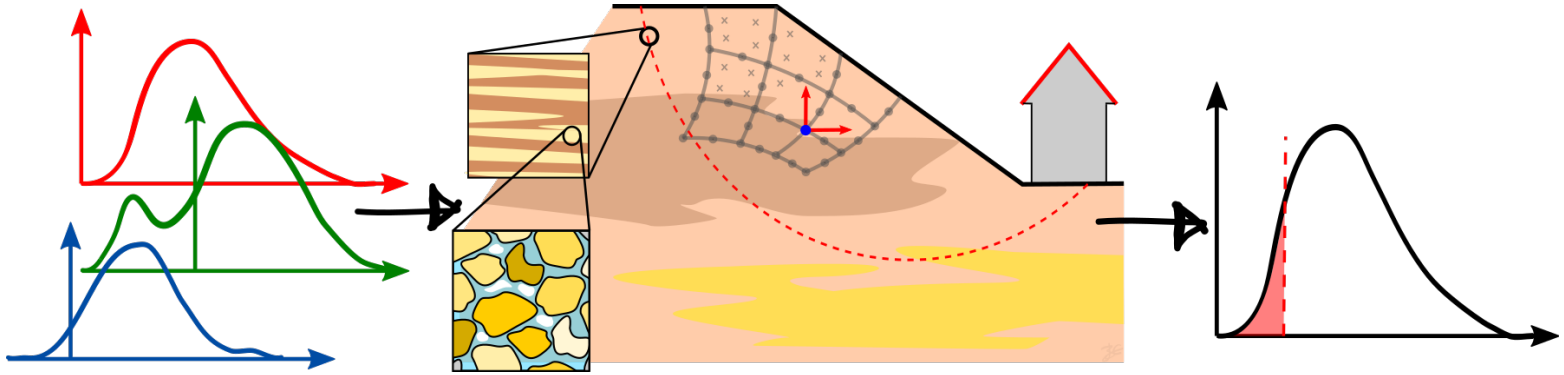
Modelling of geotechnical uncertainty

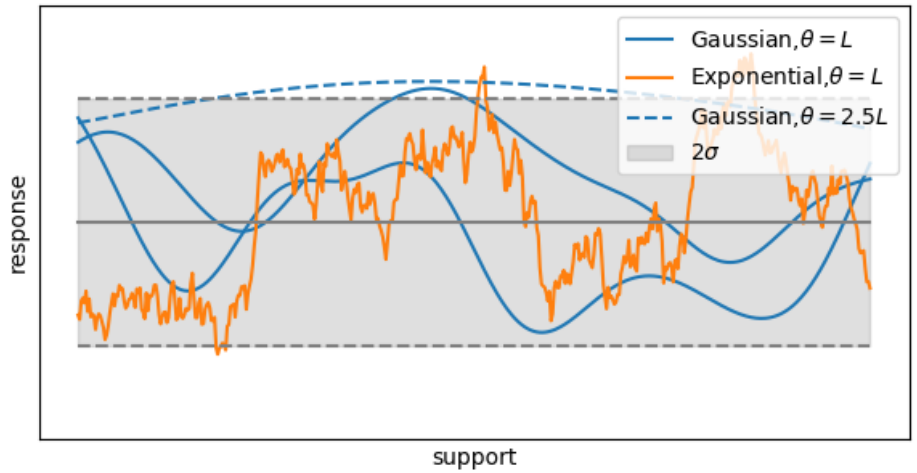
Characterisation	Modelling	Analysis
Geotechnical uncertainty	Soil mechanics of heterogeneous material	Geotechnical reliability

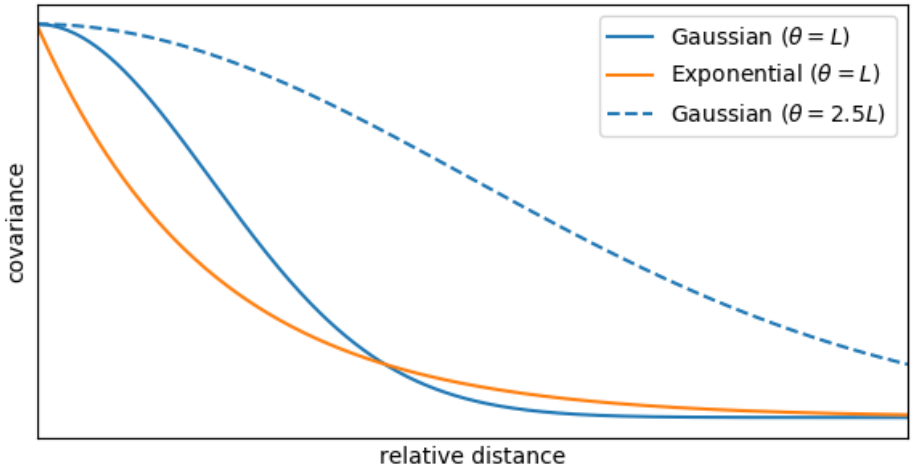


Content

- Some (random field) theory
- **Characterisation** of geotechnical uncertainty
- **Modelling** of heterogeneity
- Reliability **analysis**

Random field theory / GP / Kriging

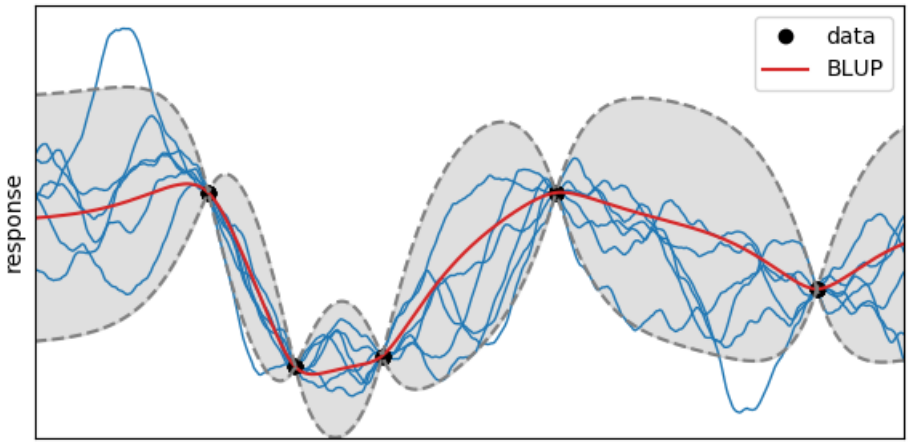


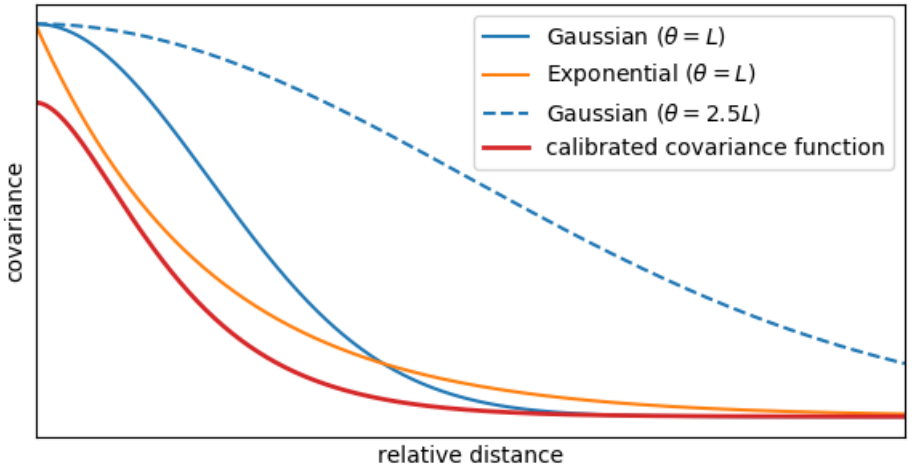


Random fields

- gaussian
- mean trend
- covariance function

Random field theory / GP / Kriging





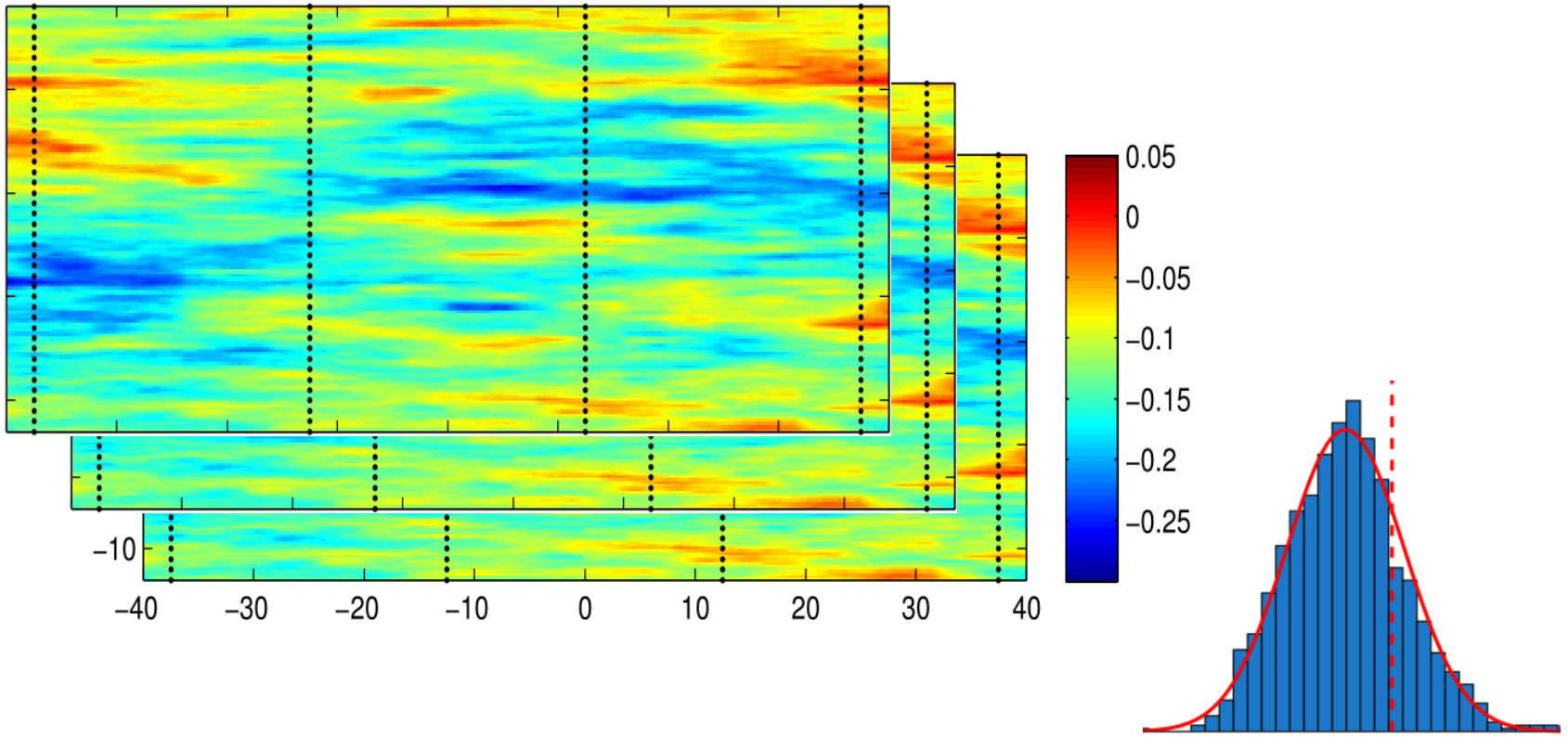
Random fields
- gaussian
- mean trend
- covariance function

Conditional random fields
- mean trend
- covariance function
- data

Kriging ::
- best linear unbiased prediction (BLUP)
- prediction variance (gaussian)

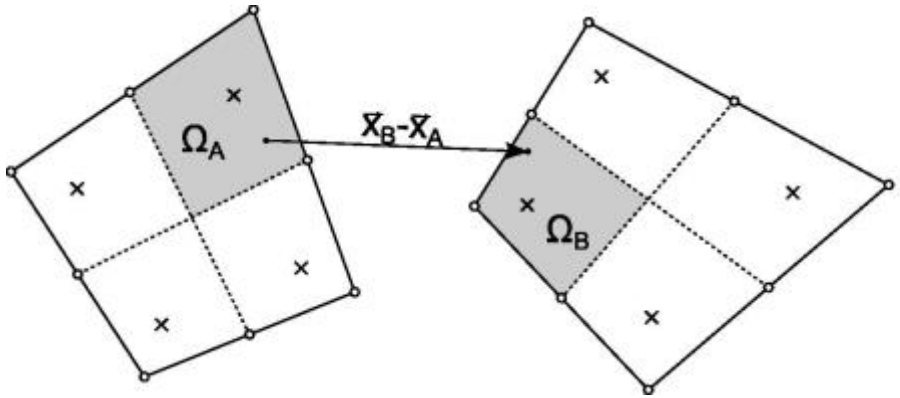
Characterisation

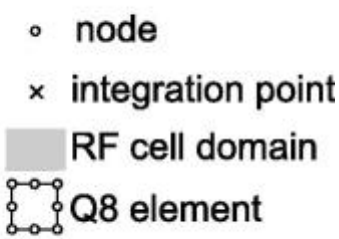
of geotechnical uncertainty

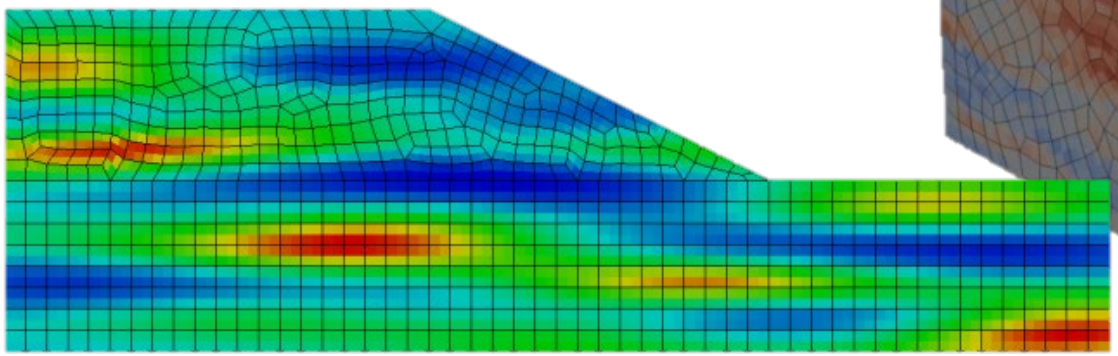


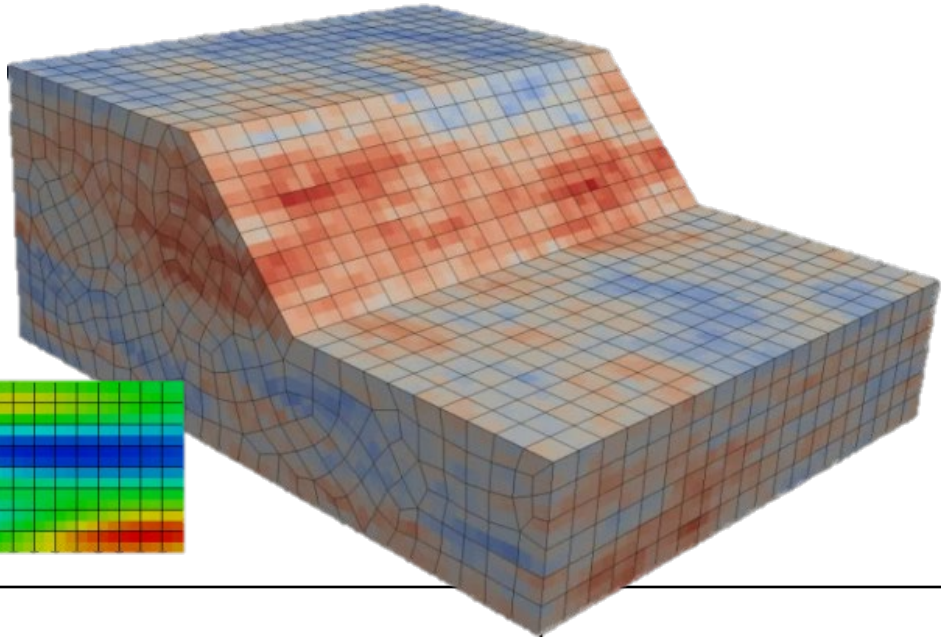
van den Eijnden, AP; MA Hicks (2011). Conditional simulation for characterizing the spatial variability of sand state. In Proc. 2nd Int. Symp. Comp. Geomech., Croatia (pp. 288-296).

Modelling

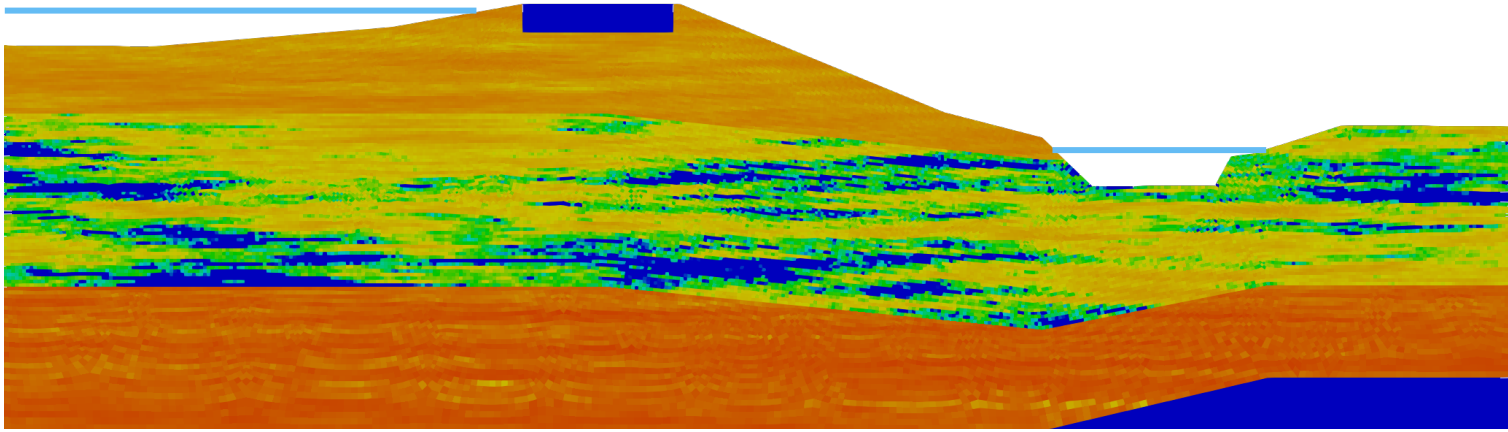

Ω_A
$\bar{x}_B - \bar{x}_A$
Ω_B

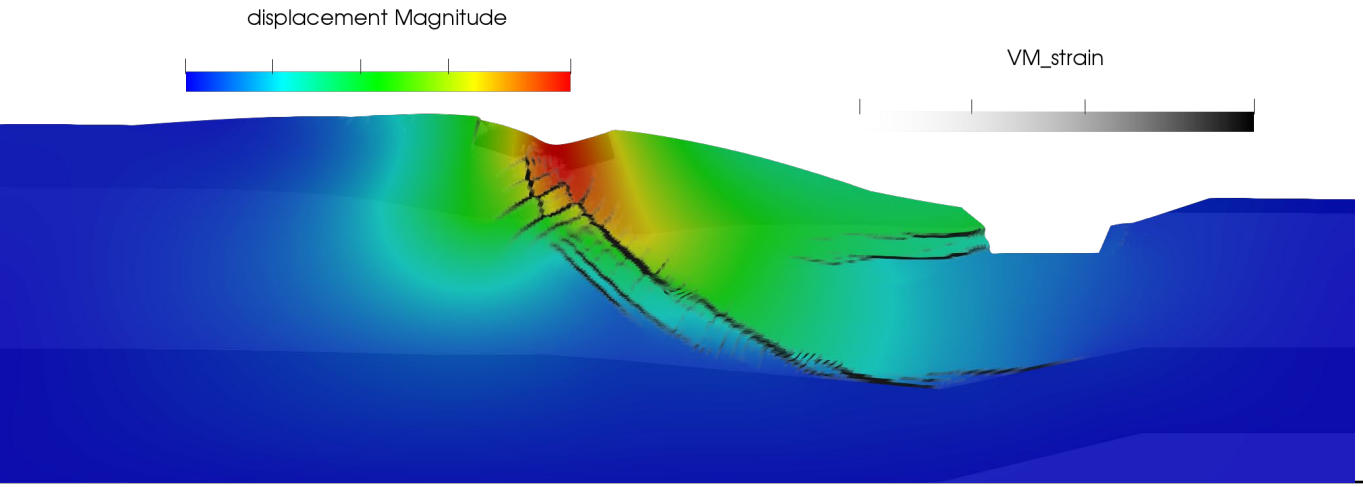

node
integration point
RF cell domain
Q8 element



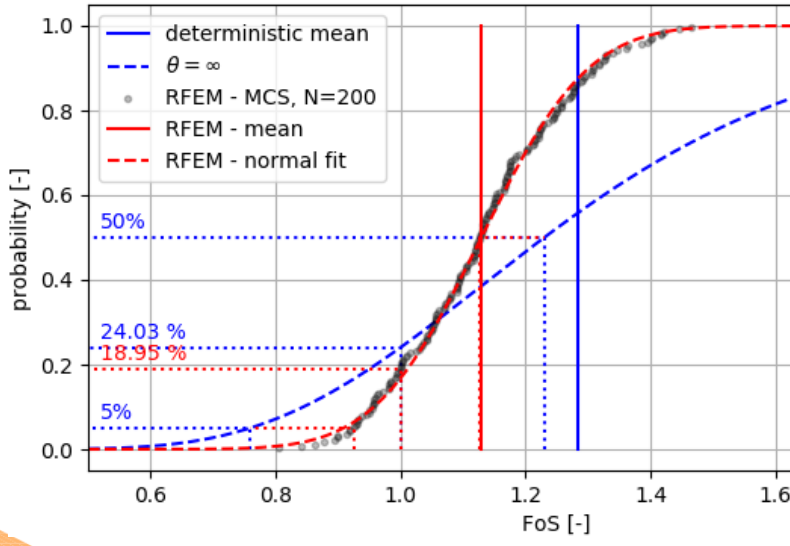


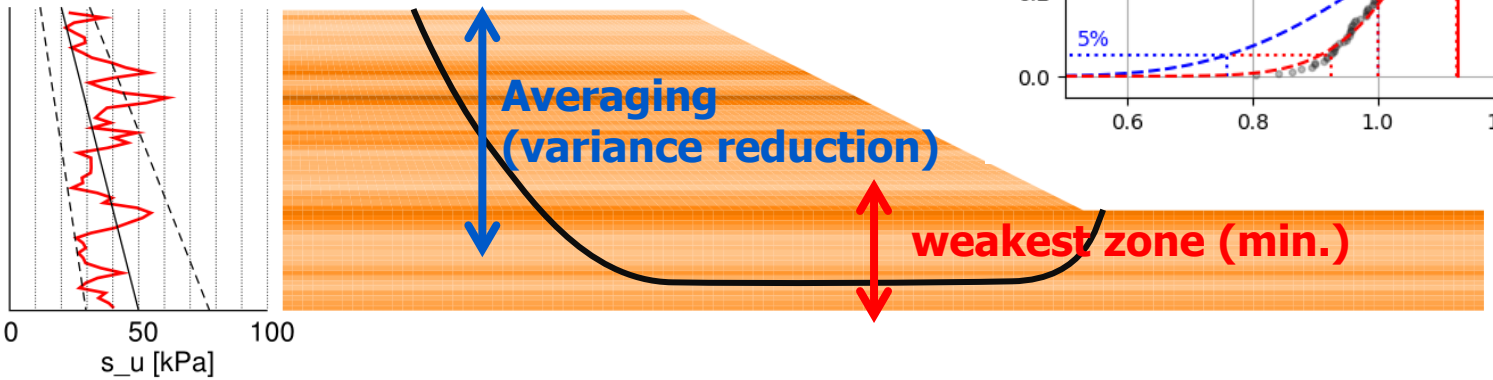
Modelling

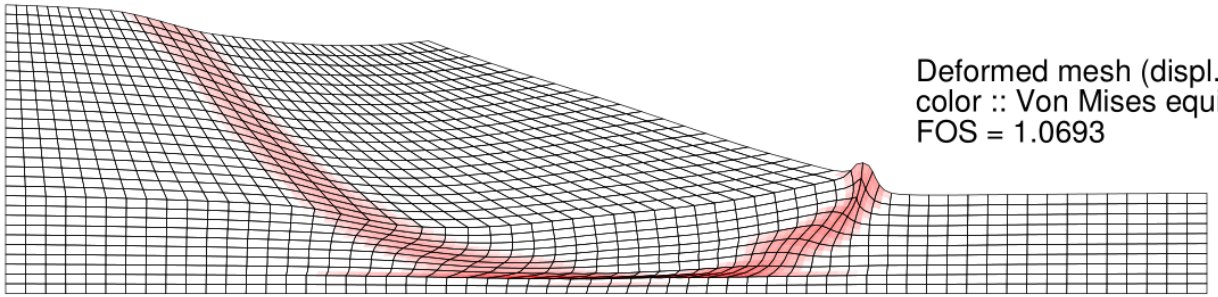




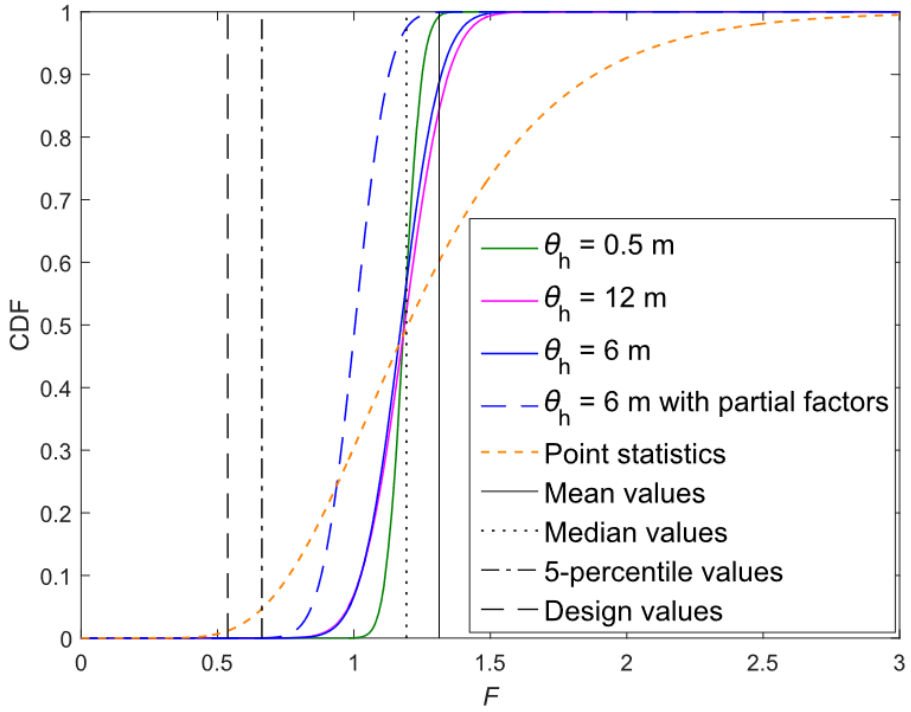
Modelling / analysis

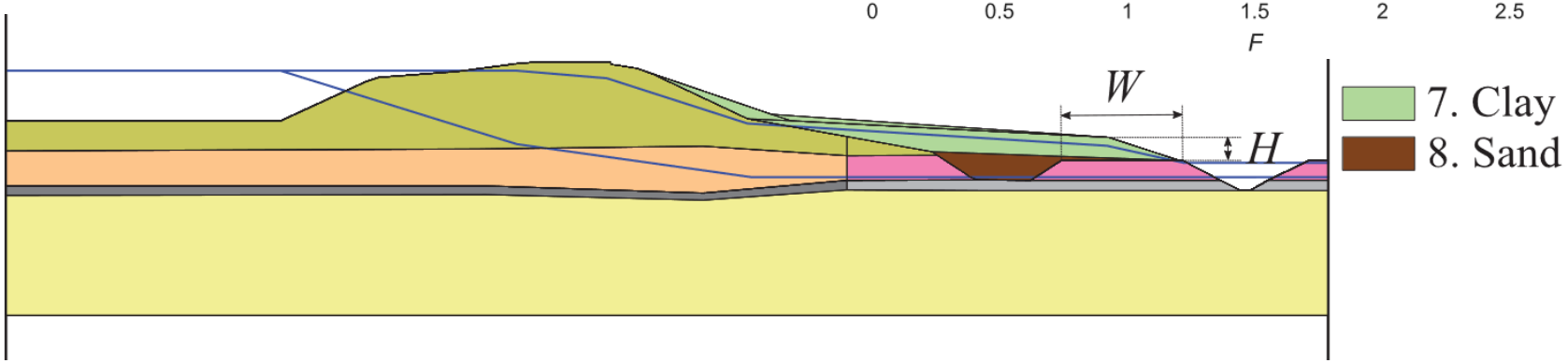






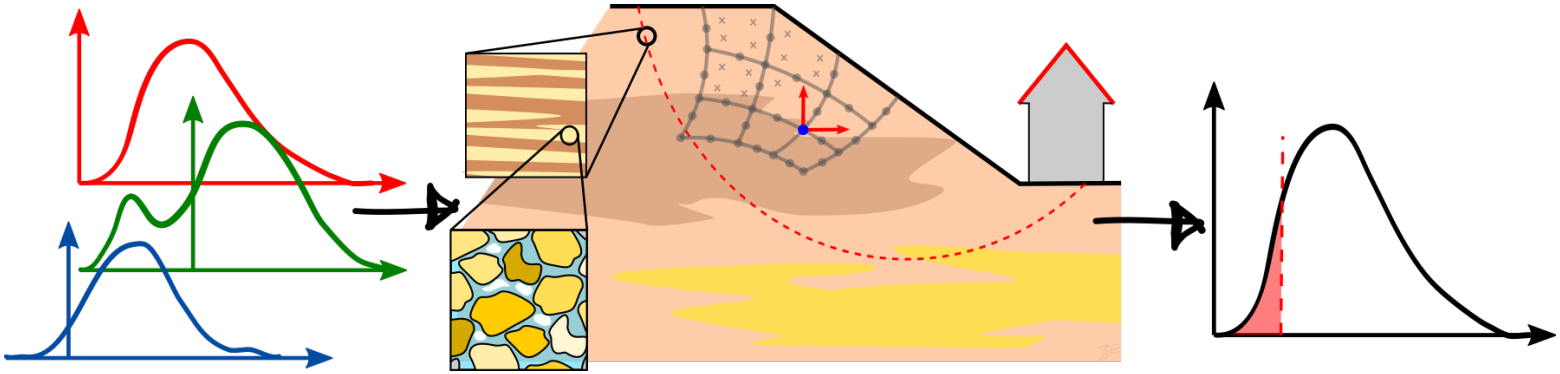
Reliability analysis
regional dyke





Hicks, MA; D Varkey; AP van den Eijnden; T de Gast; P Vardon (2019) On characteristic values and the reliability-based assessment of dykes. *Georisk: Assessment and Management of Risk for Engineered Systems and Geohazards* 13:4,313-319

Reliability analysis



Reliability analysis

Sheetpile in dyke

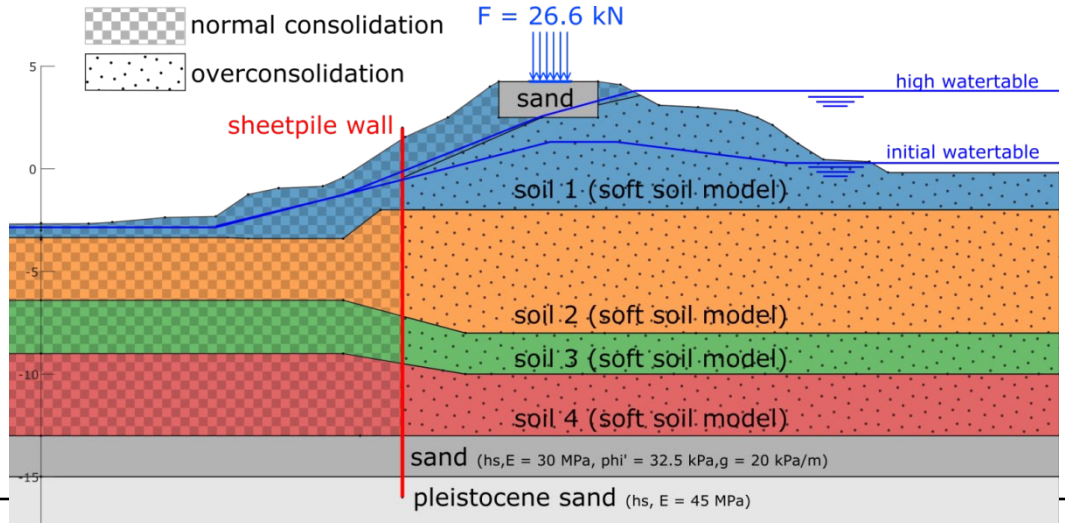
	$\tan(\phi)$ $\sim LN(\mu, \delta = 0.1)$		λ^{-1} $\sim LN(\mu, \delta = 0.1)$		σ_y^{NC} [kPa] $\sim N(\mu, \delta = 0.21)$		σ_y^{OC} [kPa] $\sim N(\mu, \delta = 0.21)$	
	μ	X_i	μ	U_i	μ	X_i	μ	X_i
soil 1 *(dyke clay)*	0.40	X_1	18.48	X_5	22.5	U_9	65.0	U_9
soil 2 *(sandy clay)*	0.36	X_2	29.90	X_6	22.5	U_{10}	125.0	U_9
soil 3 *(peat)*	0.66	X_3	5.40	X_7	60.0	U_{10}	155.0	U_9
soil 4 *(heavy clay)*	0.30	X_4	13.31	X_8	120.0	U_{10}	180.0	U_9

Computation stages

1. initial condition
2. sheetpile wall installation
3. high water conditions
4. traffic crest load

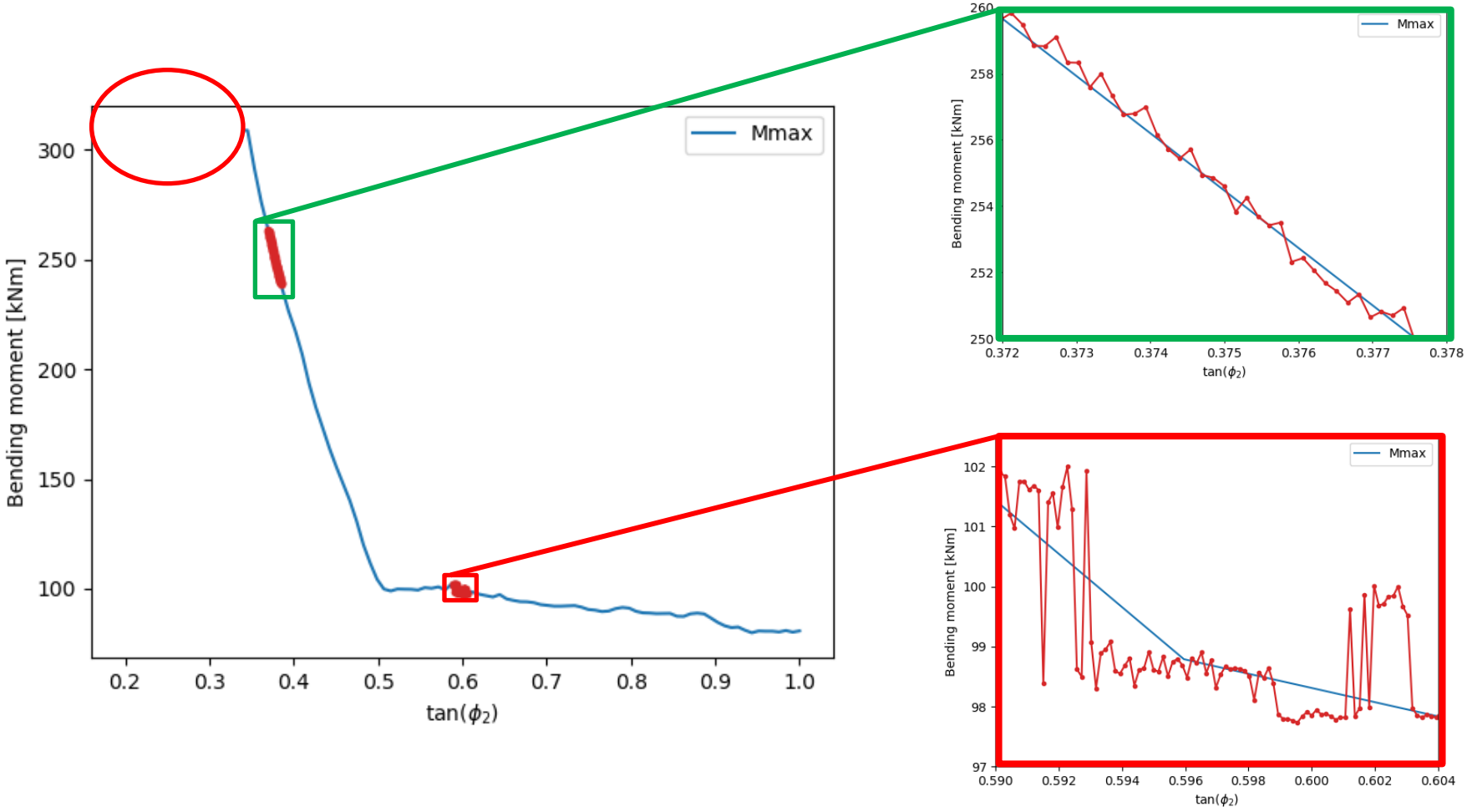
Target reliability

$\beta \approx 5.0$ $\quad$ $P_f \approx 10^{-7}$



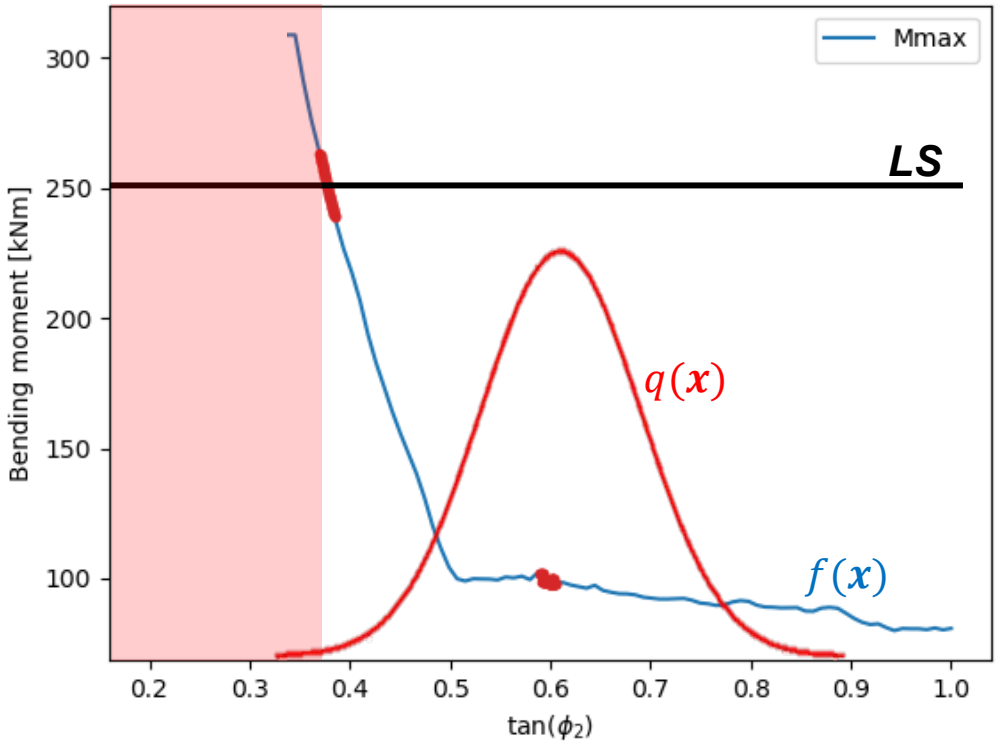
Reliability analysis

Sheetpile in dyke



Reliability analysis

Sheetpile in dyke - example



probability of failure

$$P_f = \int_{\Omega} q(\boldsymbol{x}) I_f(\boldsymbol{x})\, d\boldsymbol{x}$$

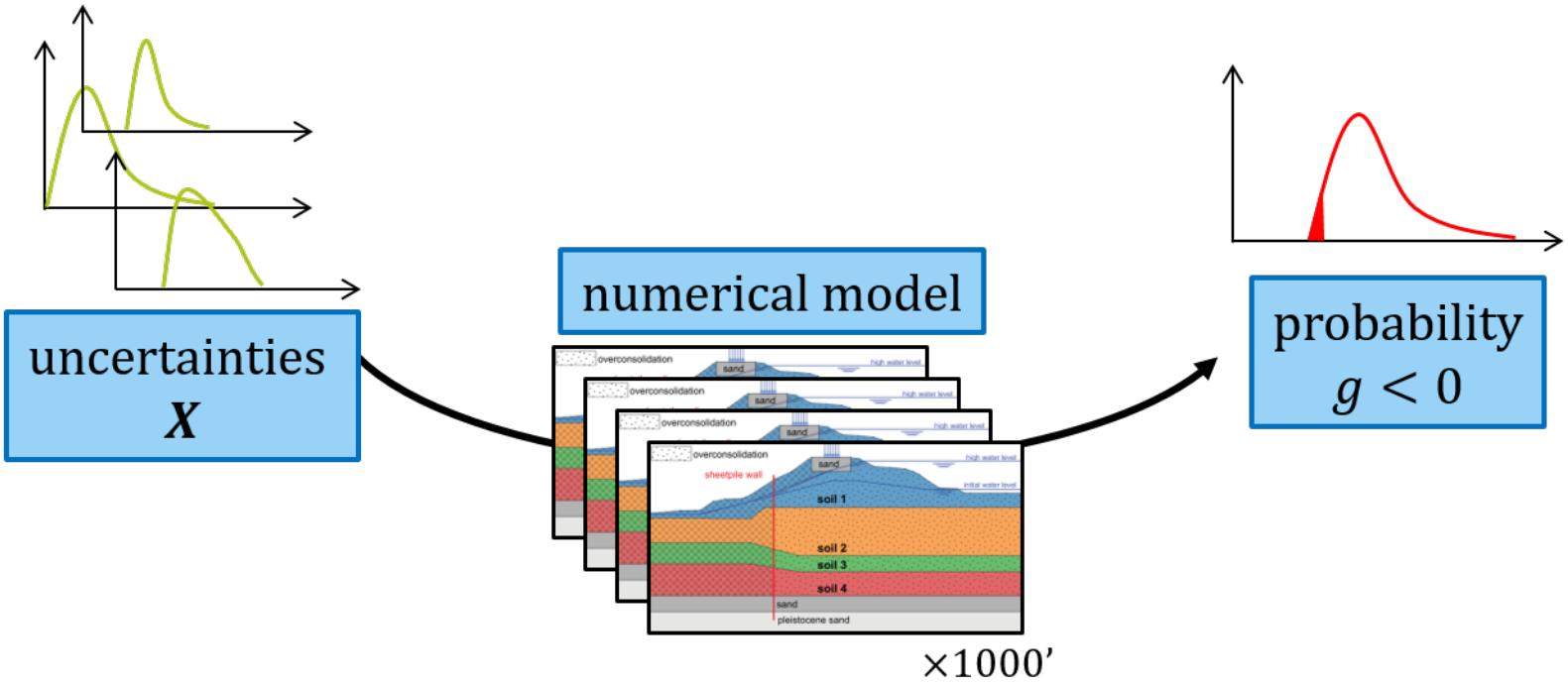
$$I_f(\boldsymbol{x}) = \begin{cases} 1 & \forall \quad f(\boldsymbol{x}) \geq \boldsymbol{LS} \\ 0 & \forall \quad f(\boldsymbol{x}) < \boldsymbol{LS} \end{cases}$$

Multivariate, complex model:

MCS → 1000' model runs

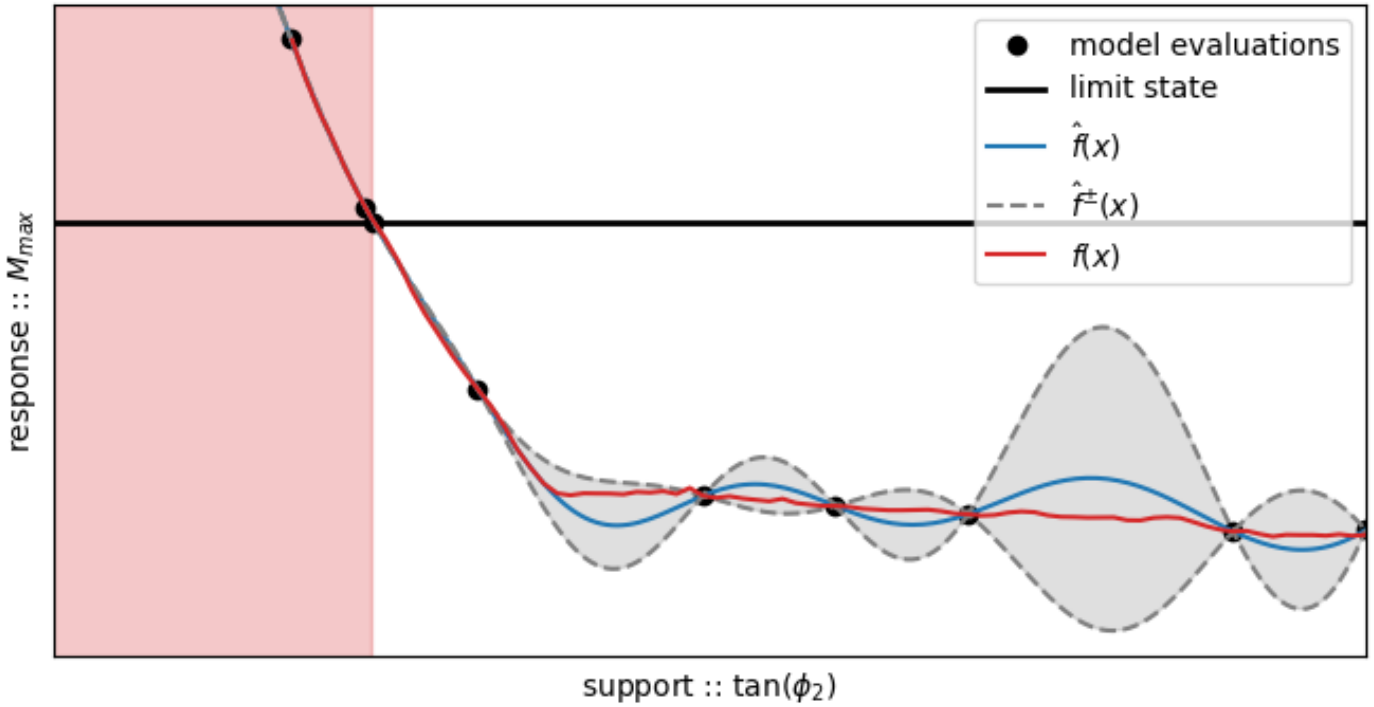
Reliability analysis

Meta-modelling



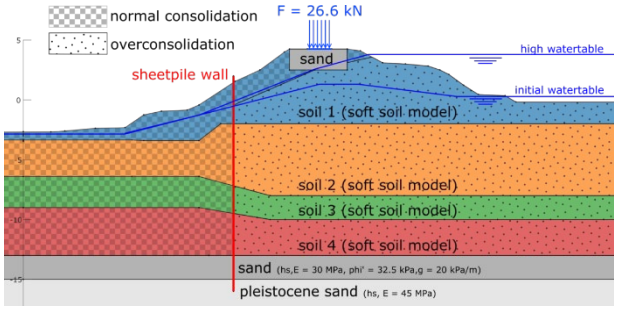
Reliability analysis

Meta-modelling: active learning GPR



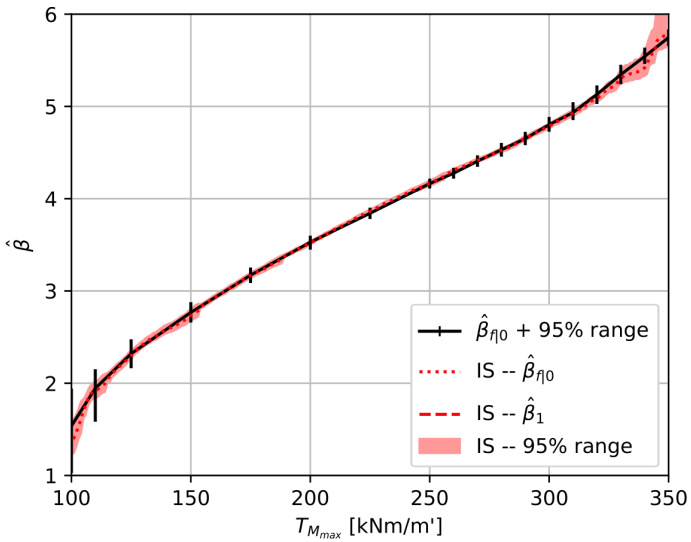
Reliability analysis

Meta-modelling: active learning GPR



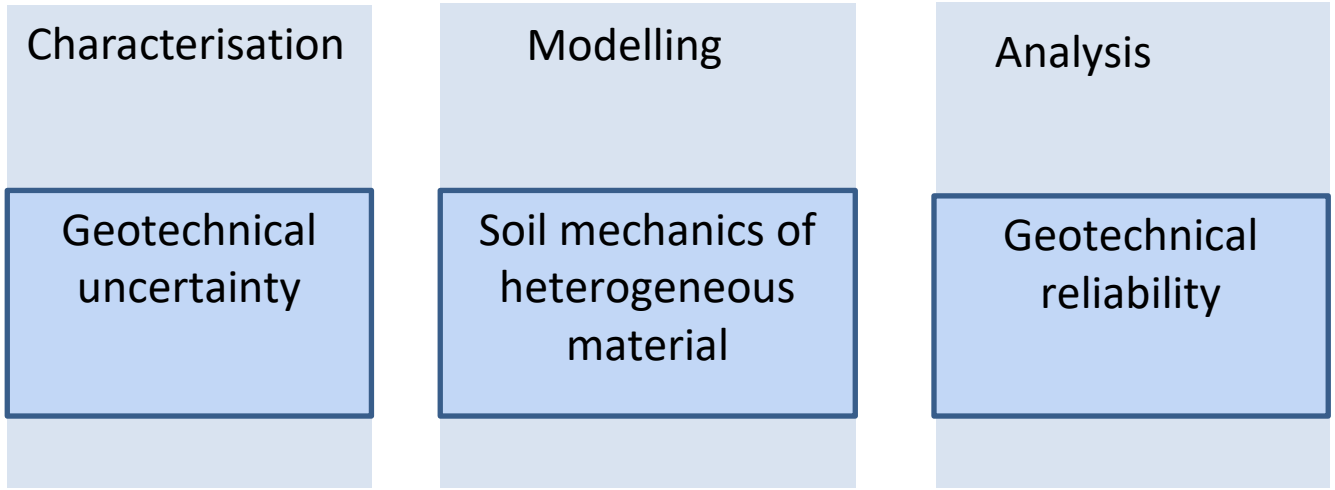
Efficient and robust reliability analysis for geotechnical applications:

- noisy, incomplete, non-linear and computationally expensive models
- small probabilities ($P_f \sim 10^{-7}$)
- ~10 significant stochastic variables
- fully probabilistic, high accuracy



van den Eijnden, AP; T Schweckendiek; MA Hicks (2021) Metamodelling for geotechnical reliability analysis with noisy and incomplete models. *Georisk: Assessment and Management of Risk for Engineered Systems and Geohazards* (accepted)

Modelling of geotechnical uncertainty



Thank you for your attention

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$$\varepsilon_{33} = \alpha \dot{\varepsilon}_{load}$$