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Characterization of spatial variability with observed responses: application of displacement back estimation

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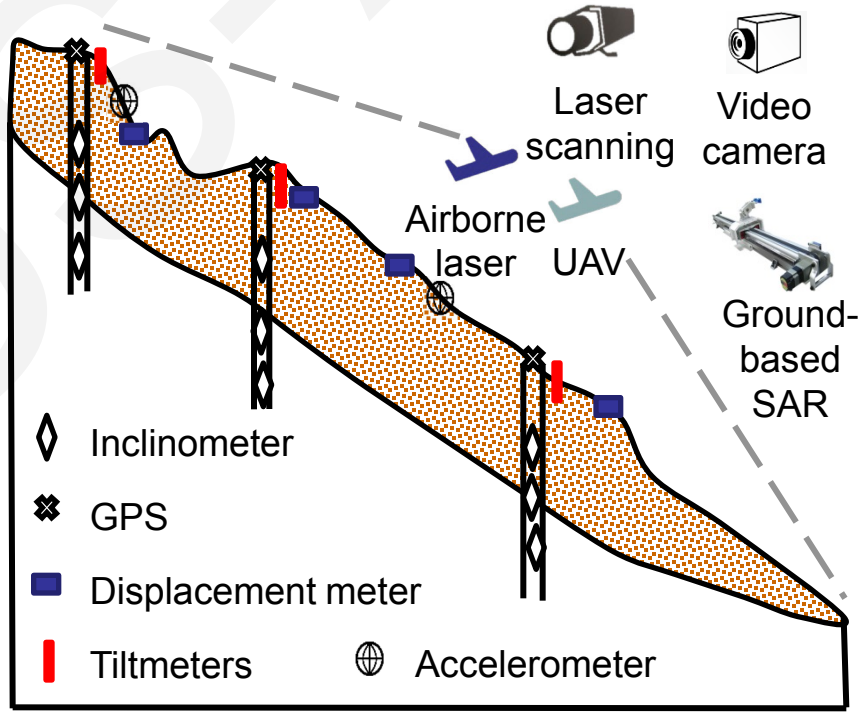
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Introduction: spatial variability & displacement response

- Soil parameters measured by field and laboratory tests may not be able to be used directly to predict soil behavior due to significant spatial variability.
- Estimation of field spatial variability based on field responses using inverse methods might be an alternative way.



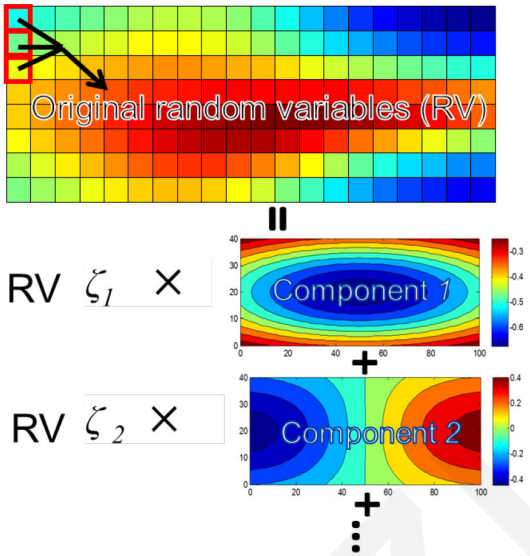
Spatial variability of soil slopes



Slope monitoring of displacement

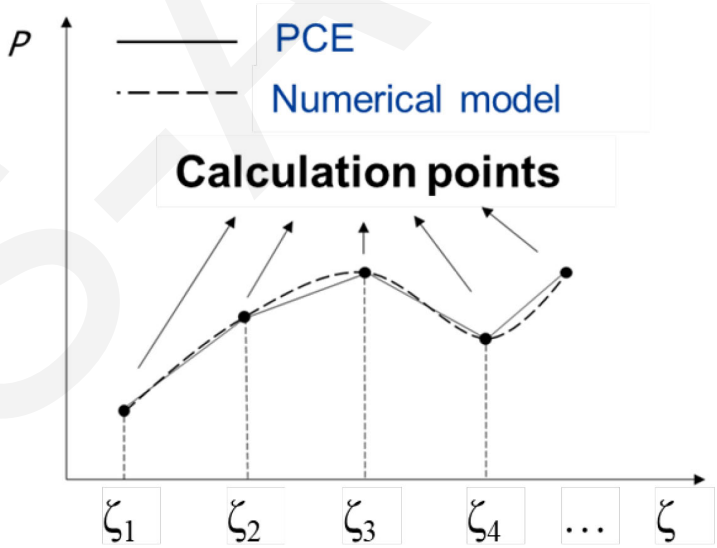
Methods: Karhunen–Loève + polynomial chaos + MCMC

- Karhunen–Loève:



$$E(\mathbf{x}) = \mu(\mathbf{x}) + \sum_{i=1}^{n} \sqrt{\lambda_i}\,\xi_i \varphi_i(\mathbf{x})$$

- Polynomial chaos:



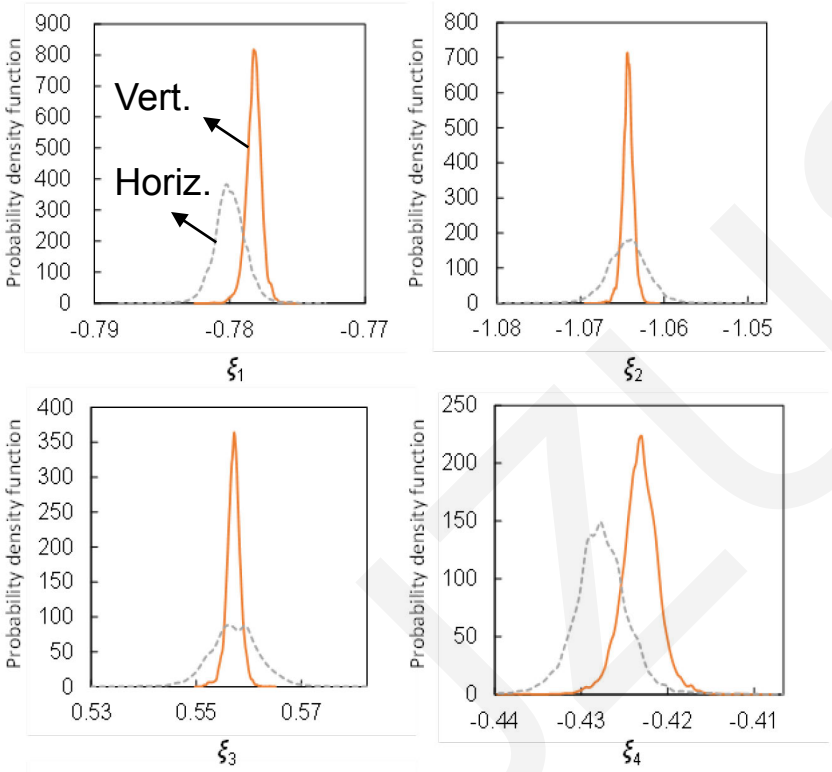
$$P(\xi) \approx P_s(\xi) = \sum_{j=0}^{k-1} c_j \Psi_j(\xi),$$

- MCMC:

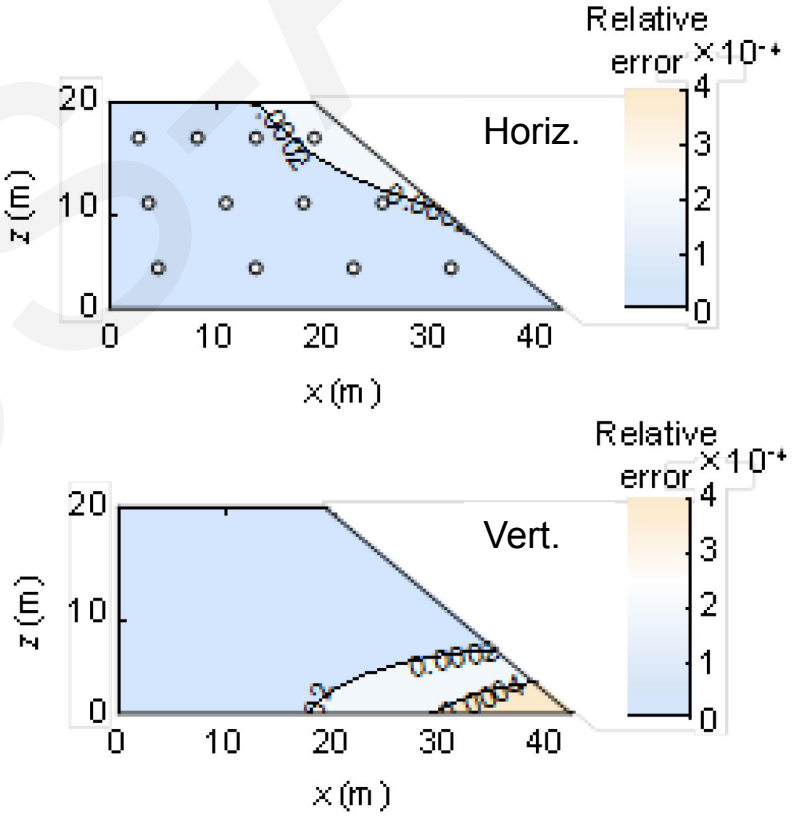
$$h(\xi \mid \hat{\boldsymbol{P}}) = K \cdot \prod_{i=1}^{d} \frac{1}{\sqrt{2\pi\sigma_\varepsilon^2}} \exp\left(-\frac{(P_{si}(\xi) - \hat{P}_i)^2}{2\sigma_\varepsilon^2} \right) \cdot h(\xi).$$

Results: effect of type of displacements

- Estimation based on horizontal displacements was more accurate, and horizontal displacements are preferred for displacement back estimation of the spatial variability of *E*.

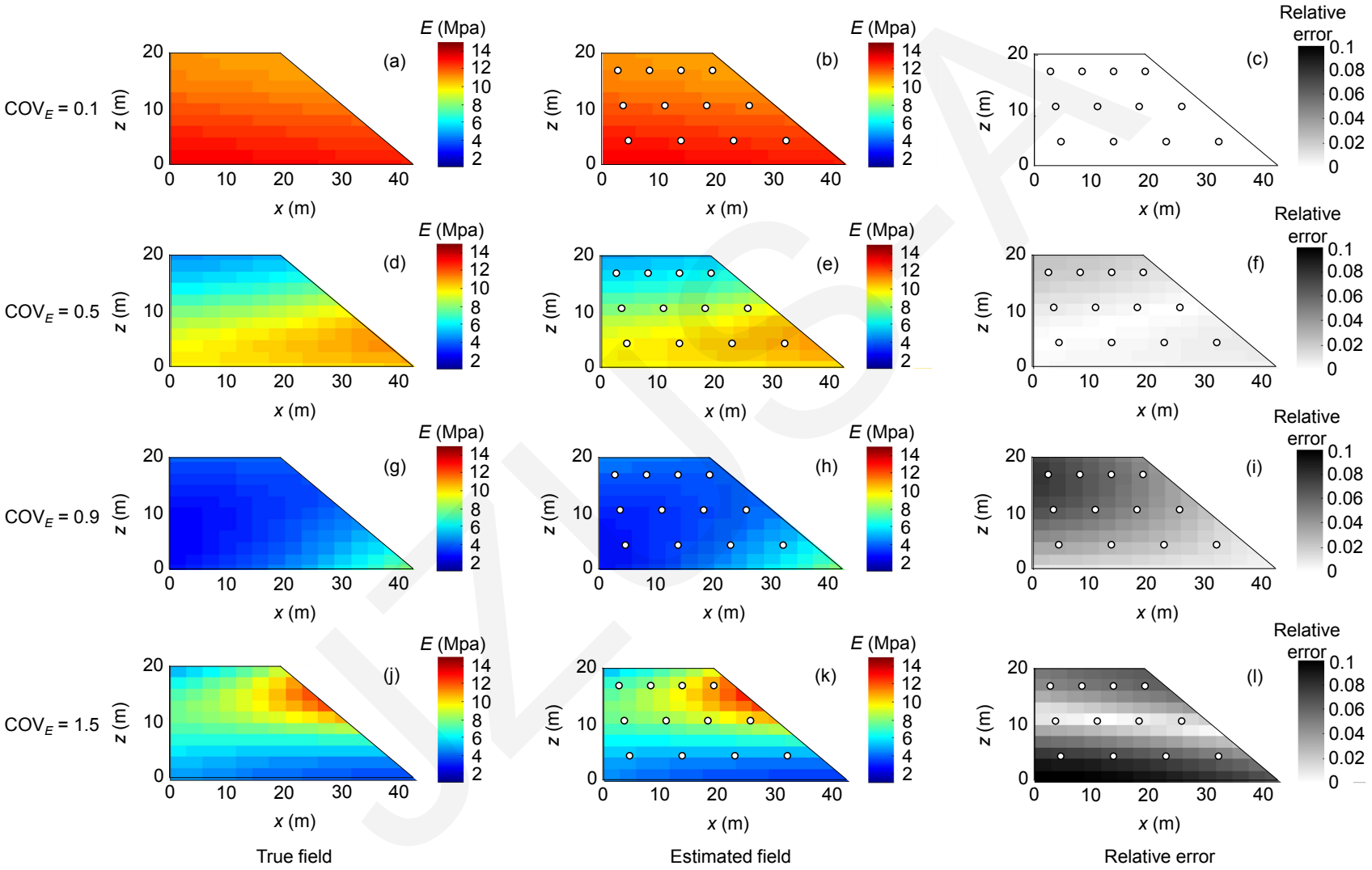


Figs 1. Posterior distributions based on horizontal and vertical displacements



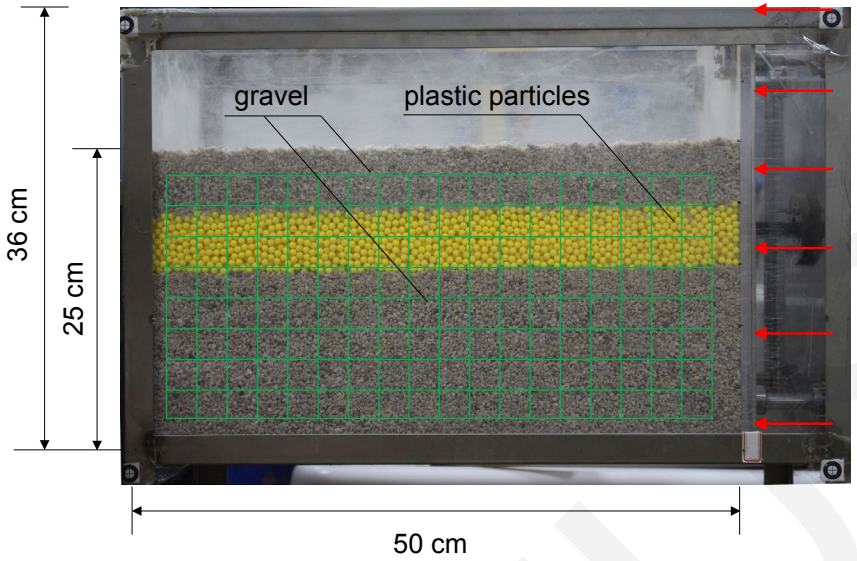
Figs 2. Relative error of the estimated field

Results: effect of type of COV



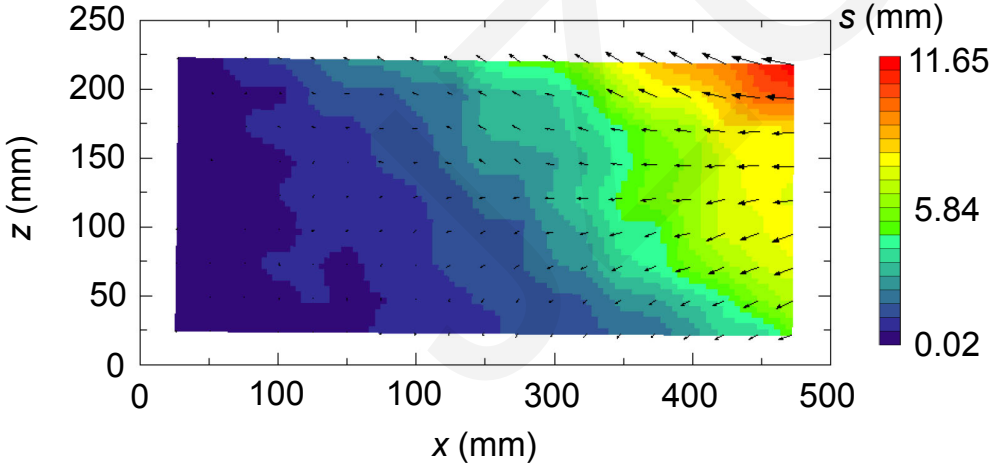
Figs 3. True field and estimated field of E for $\mathrm{COV}_E = 0.1, 0.5, 0.9, 1.5$

Verification: Investigation based on laboratory model tests



Set up of the model test

- Two types of materials, i.e., gravel and plastic particles, were used to simulate a ground with layers of soils.
- Particle Image Velocimetry (PIV) technique

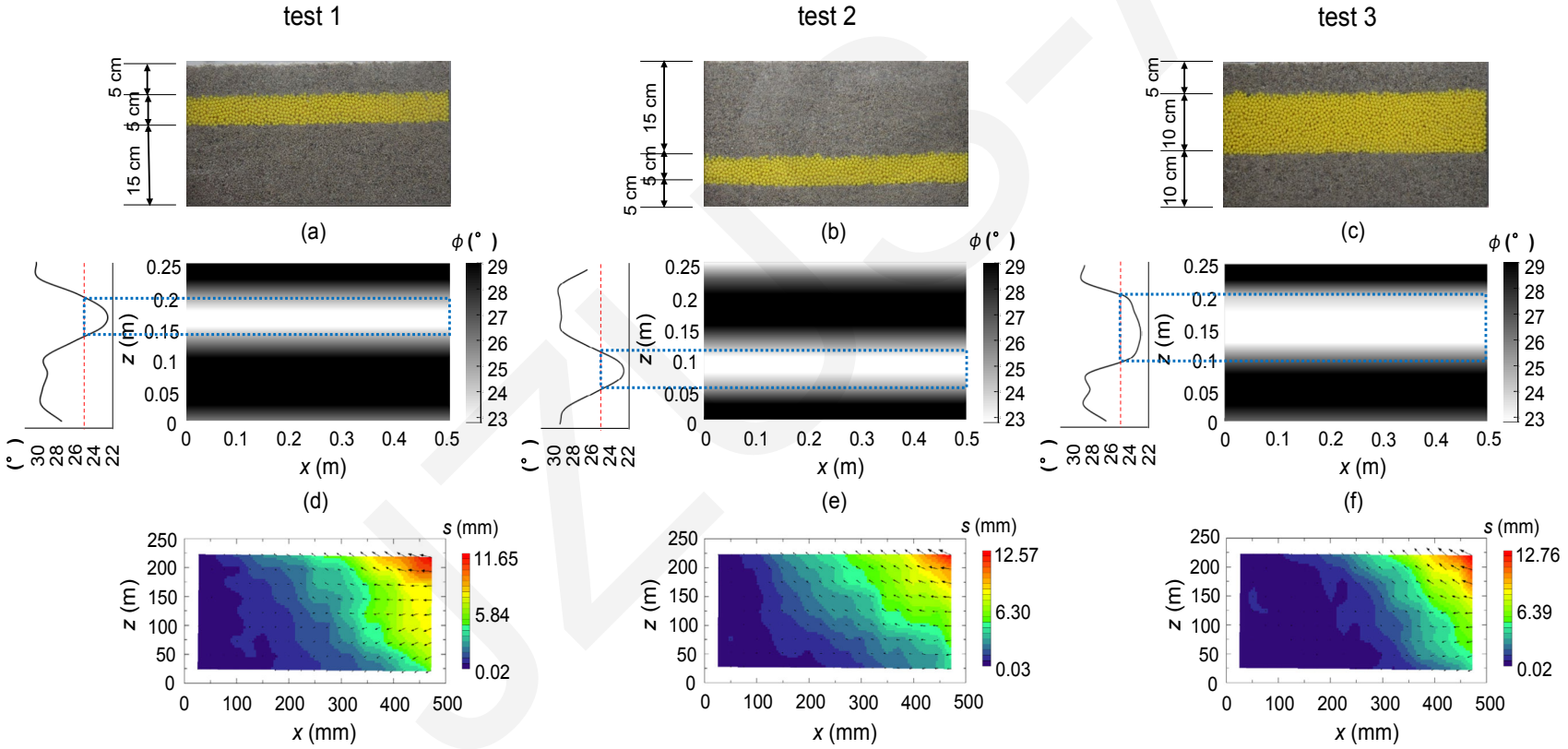


Measured displacement distribution

- A force was applied on a panel on the right side of the box causing deformation of the ground.

Verification: Investigation based on laboratory model tests

- The estimated thicknesses of the plastic particle layer is only slightly different from the actual situation.
- The location and thickness had no significant effect on the estimation.



Figs 5. Soil layers in the domain, the estimated field of ϕ and the measured displacement.

Conclusions

- The maximum relative errors based on horizontal and vertical displacements were only 0.02% and 0.04%, respectively. The use of horizontal displacement is preferable to the use of vertical displacement for back estimation.

- For the verification example of model tests, the soil layers in the artificial ground could be identified and the estimation error of the friction angle was less than 10%. The estimated thicknesses of the plastic particle layer is only slightly different from the actual situation.