Application of global sensitivity analysis methods in geotechnical problems

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Abstract. In general, the remarkable amount of uncertainties involved in the material parameters is considered as an explicit feature of any geotechnical problems, due to their geological origin. Therefore, in the context of model calibration and validation, conducting a sensitivity analysis is substantial as the first step. It identifies key input factors that have the most contribution to the uncertainty of the model output. This study employs three commonly used sensitivity analysis methods on a sophisticated geotechnical problem. The simulation of the excavation and operation of a solution-mined cavity in the rock salt, used as compressed air energy deals with highly non-linear phenomena, and includes many constitutive parameters as input. Sensitivity measures of different variables involved in the mechanical response of the cavern are computed by different global sensitivity methods, namely Sobol´/Saltelli, Random Balance Design, and Elementary Effect (Morris) method. An interpretation of the sensitivity indices provided by different methods is presented through a comparative study. The obtained results reveal that the applied methods provide identical parameter importance rankings, although not all of them are able to present the same information about the system behaviour.

1. Introduction

A crucial aspect in geotechnical engineering is providing an accurate prediction of the serviceability, the stability and soil-structures interaction behaviour. To accomplish this, one needs to identify the constitutive geo-mechanical properties of the geomaterials precisely. For many decades, researchers developed measurement techniques, analytical and numerical analysis methods to infer and simulate the constitutive behaviour of geological materials. However, independent from the accuracy level of the applied methodology, the properties of geomaterials, as a natural heterogeneous material, are associated with a significant amount of uncertainties. Despite the inherent randomness of soil properties (also known as aleatoric uncertainty), there is another category of uncertainty called as epistemic uncertainty. The latter one is mostly due to the lack of available knowledge about the natural phenomena. In geotechnical applications, the epistemic uncertainties mainly result from the existing uncertainties in the experimental and in-situ investigation and their interpretation for estimating the input factors. Thereupon, epistemic uncertainty can be reduced or even omitted by conducting an adequate amount of informative measurements and explorations. In the following, model calibration methods, either deterministic or probabilistic ones can provide an accurate assignment of the geomaterial properties.

Generally, the response of a system is not affected equally by all the involved factors. On the other hand, reducing the associated uncertainty in some input parameters may decrease noticeably the uncertainty measures in the model response, compared to the others. Hence, identifying those dominating input variables enables an effective selection of the measurement design. In this regard, the Sensitivity Analysis (SA) can be employed to detect the key input factors which have the greatest impact on the model output variation. In practice, two main categories of SA methods can be distinguished, the local SA category and the global one. In the local approach, the effect of a small variation of a single input parameter on the model output is investigated, while all the other factors are fixed. This approach also is known as one at a time and involves partial derivatives. The local methods can be considered as the historically