PS The Influence of Censoring Bias on the Characterization of Discontinuity Networks*

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Abstract

A common method to evaluate the degree of fracturing in the subsurface is the sampling of fracture characteristics at analogue outcrops or from well cores. They allow the generation of artificial discrete fracture networks (DFN), which can then be used to predict transport through a fractured rock mass by means of numerical simulations. Key parameters for the generation of DFN are density (number of fractures per unit area), length (e.g. fractal dimension) and orientation. The term discontinuity is used here to describe various kinds of mechanical defects, such as fractures, joints, veins, etc. However, outcrops are often covered or well sections can be damaged, so that discontinuities are difficult to impossible to identify. The presence of vegetation, debris, or damaged parts of a well core, prevents a complete sampling of discontinuities and thus increases the degree of sampling bias. The term cover is used to account for all factors that render an outcrop or well core partly unobservable. Our aim is to investigate how, and to which extent, cover influences sampling bias and causes deviations of the estimated key parameters from the true values.

Before investigating natural discontinuity systems we quantify the effect of cover using artificial 2D discontinuity networks with known input parameters. The percentage of cover is increased stepwise. We compare the results by applying several standard sampling methods: 1) window sampling, 2) scanline sampling, and 3) circular scanlines. These methods are affected differently by sampling bias, and thus by cover. Window sampling is mainly affected by censoring, whereas scanline sampling is strongly affected by truncation, since shorter discontinuities have a lower chance of being intersected by the scanline than the longer ones. Circular scanlines and window sampling are not subjected to sampling bias, since these are maximum likelihood estimators.

In addition, we also investigated the degree of uncertainty in density and length distribution estimates due to sampling bias. Knowing the efficiency, limitations and possible corrections of each method has allowed us to determine the best sampling technique depending on the outcrop situation and to optimize the time required to adequately capture the properties of a discontinuity network. We show how the performance of the different methods changes with increasing percentages of cover and apply this knowledge to different examples of natural discontinuity systems.

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The influence of censoring bias on the characterization of discontinuity networks

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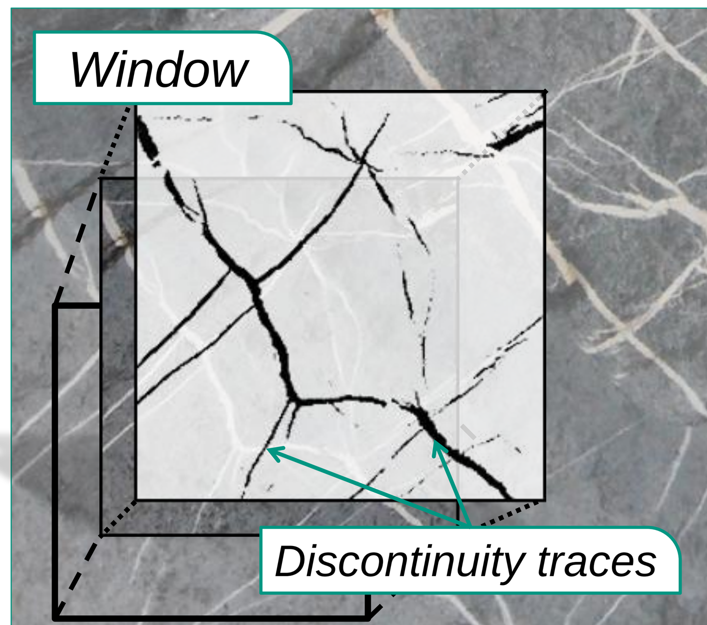

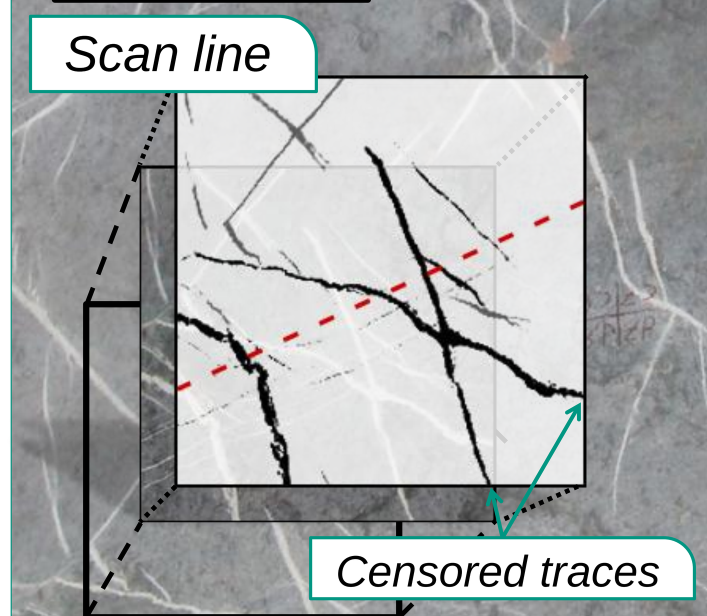

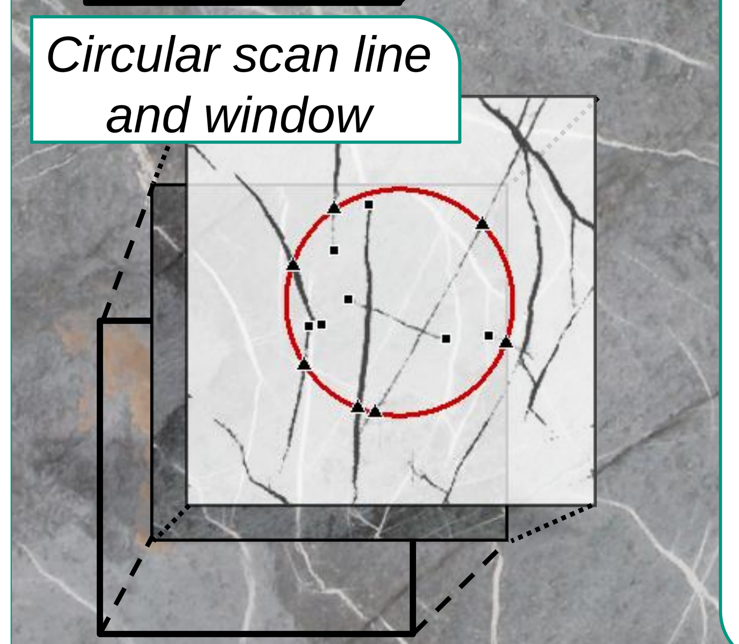

Introduction

A common method to evaluate the degree of fracturing in the subsurface is the sampling of fracture characteristics at analogue outcrops or from well cores. However, outcrops and wells are of limited extend, thus introducing censoring bias. The latter is increased even more by the presence of vegetation, debris, or damaged parts of a well core. The influence of censoring bias on the characterization of discontinuity networks is investigated by applying three commonly used sampling methods on artificial networks with known input parameters.

Methodology

Generation of artificial discontinuity networks

Nine discrete discontinuity networks were generated with input parameters of density p and exponents E for a power-law length distribution:

$$f(x) = p \cdot x^{-E}$$

The percentage of censored discontinuity traces is varied by changing the size of the sampling areas.

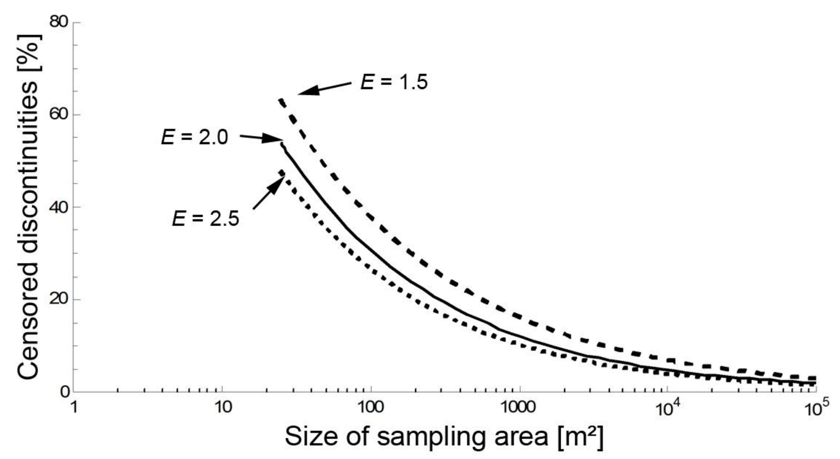

Figure 2. Relationship between sampling area size and censored discontinuities

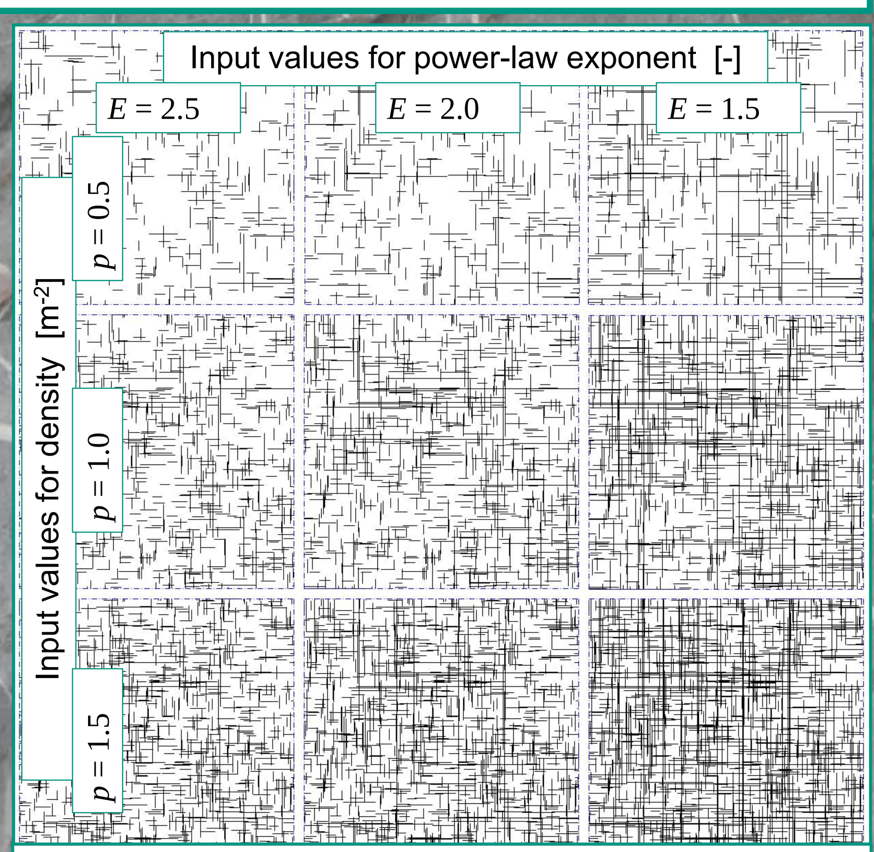

Figure 1. Illustration of the nine artificial discontinuity networks.

Assessing the influence of censoring bias

For each sampling area the censored discontinuities (in %) are plotted against the difference (in %) between input and measured values. The actual uncertainty is illustrated as lines of maximum difference.

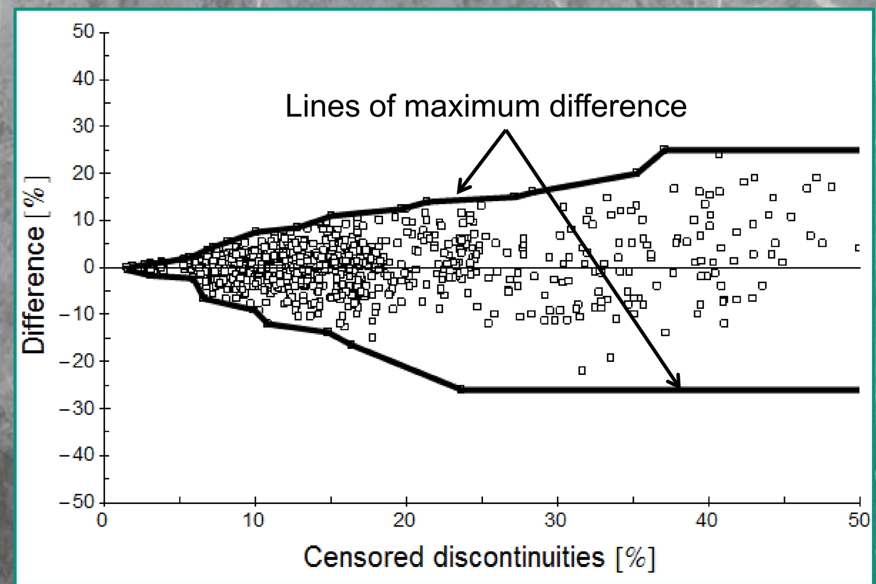

Figure 3. Influence of censored discontinuities on the difference between measured and input values for each sampling area.

Acknowledgement

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Results and Conclusion

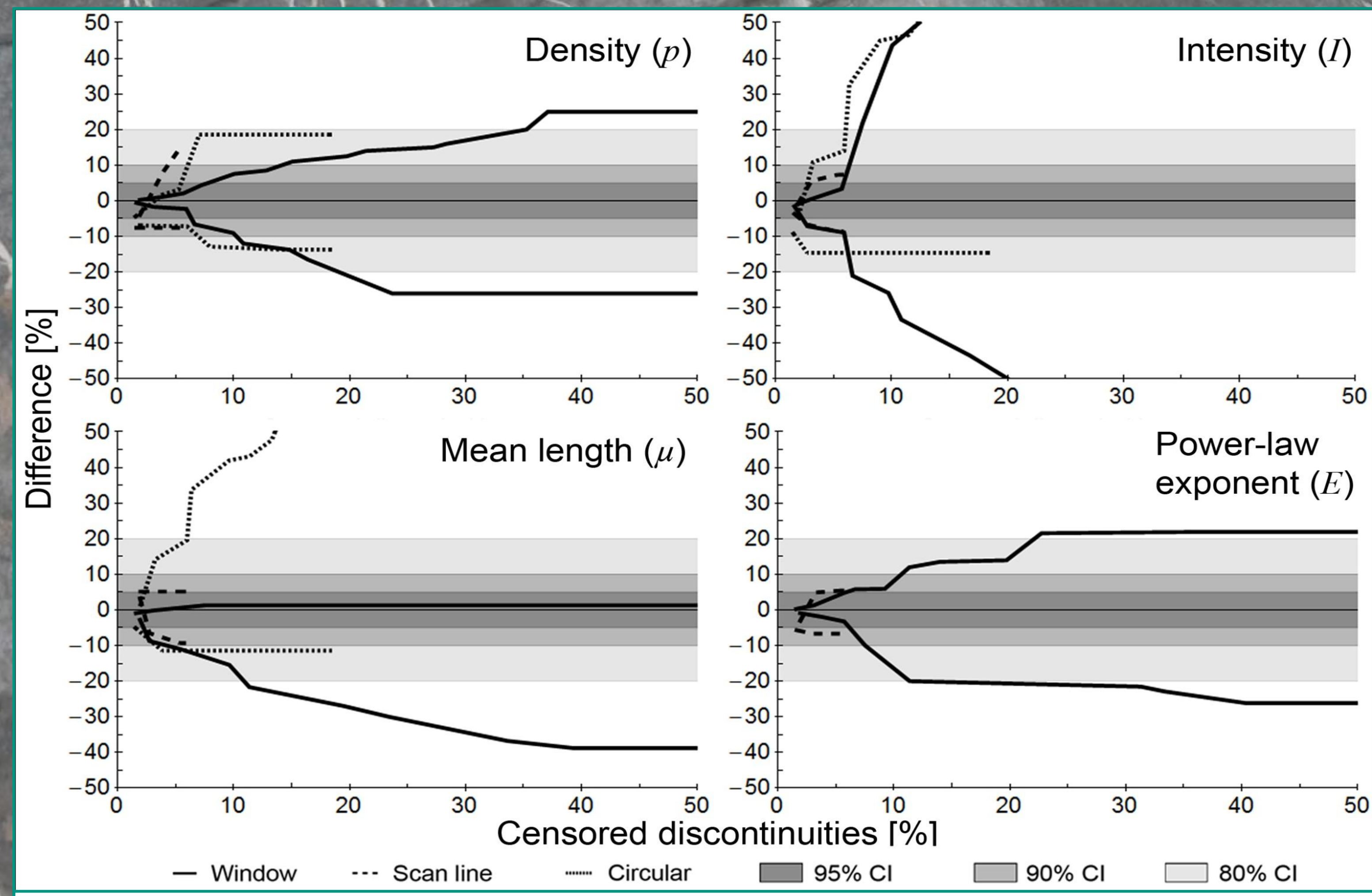

Figure 4. Lines of maximum difference for discontinuity density, intensity, mean length and length distribution evaluated by applying the three sampling methods on the artificial discontinuity networks.

A considerable influence of censoring bias on the characterization of discontinuity networks was found. The difference between measured and input values increases for higher percentages of censored discontinuities. Censoring bias introduces a significant uncertainty when evaluating the characteristics of discontinuity networks.

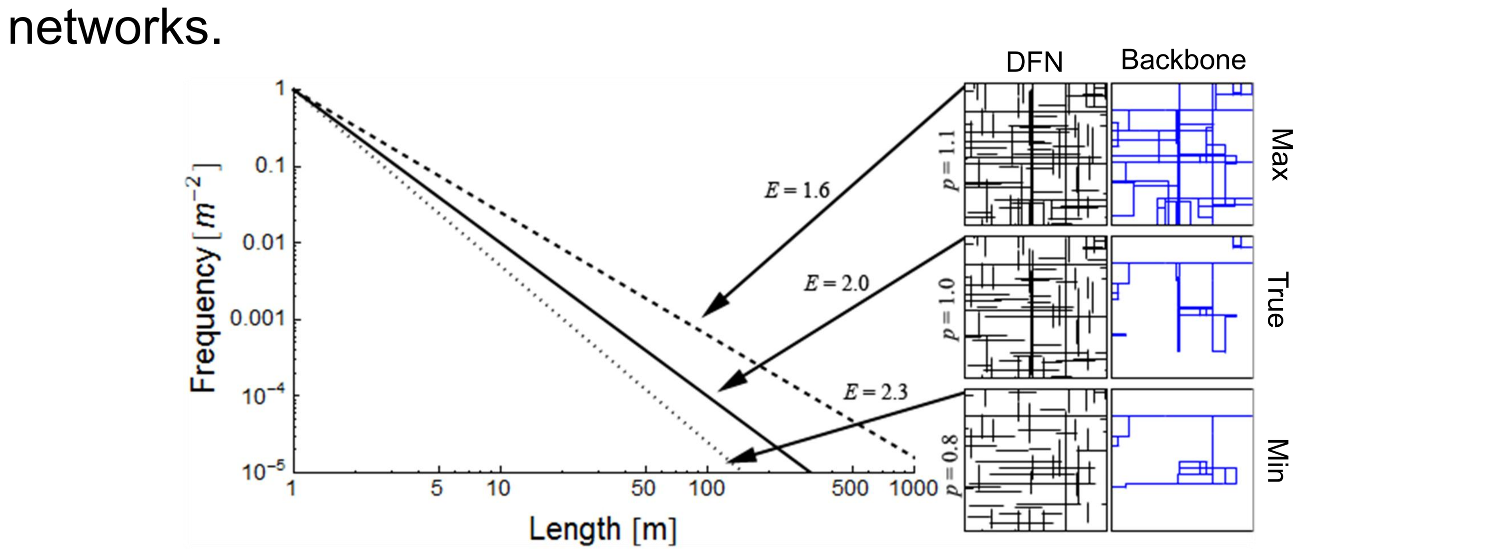

Figure 5. Illustration of the uncertainty for 20% censored discontinuities. Shown are possible lower (dotted line, bottom DFN), true (solid line, middle DFN) and upper (dashed line, top DFN) estimates for the power-law exponent E and the density p.