Impact of Geostatistical Techniques on Resource Volume and Flow

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energi SIMULATION

BACKGROUND

Fluid flow in porous media is characterized by the extreme high and low permeability regions and in particular by their continuity. Most existing geostatistical algorithms in commercially available software are based on the Gaussian (normal) assumptions. In general, a Gaussian spatial dependence implies a low spatial correlation of extremes, resulting in an underestimation of the connectivity of high and low permeability regions.

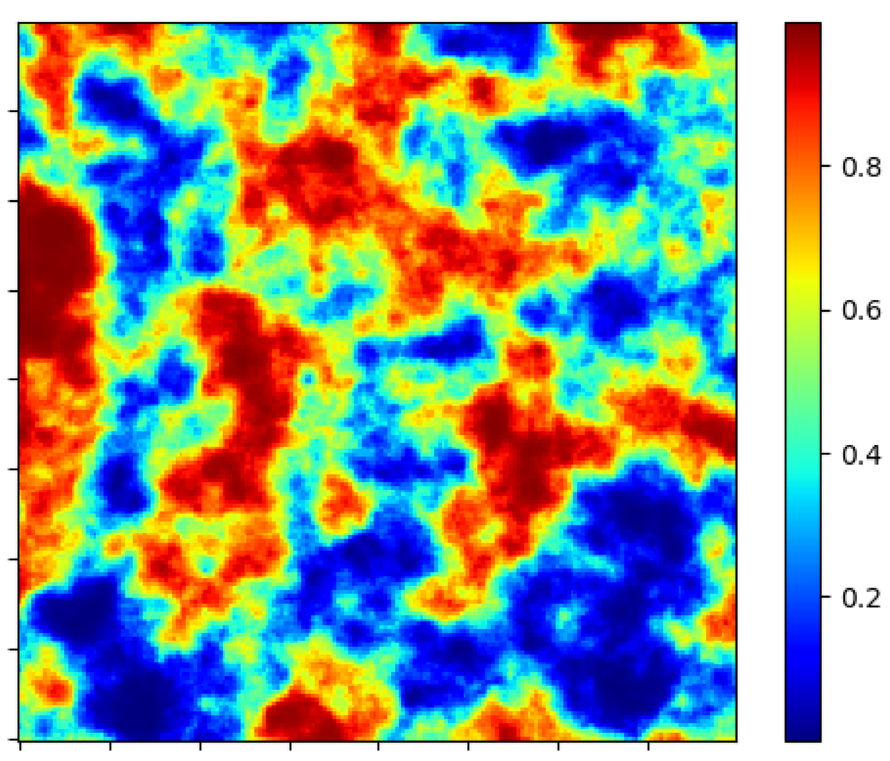

Fig1: Gaussian spatial random field with isolated extreme values

METHODOLOGY

1.

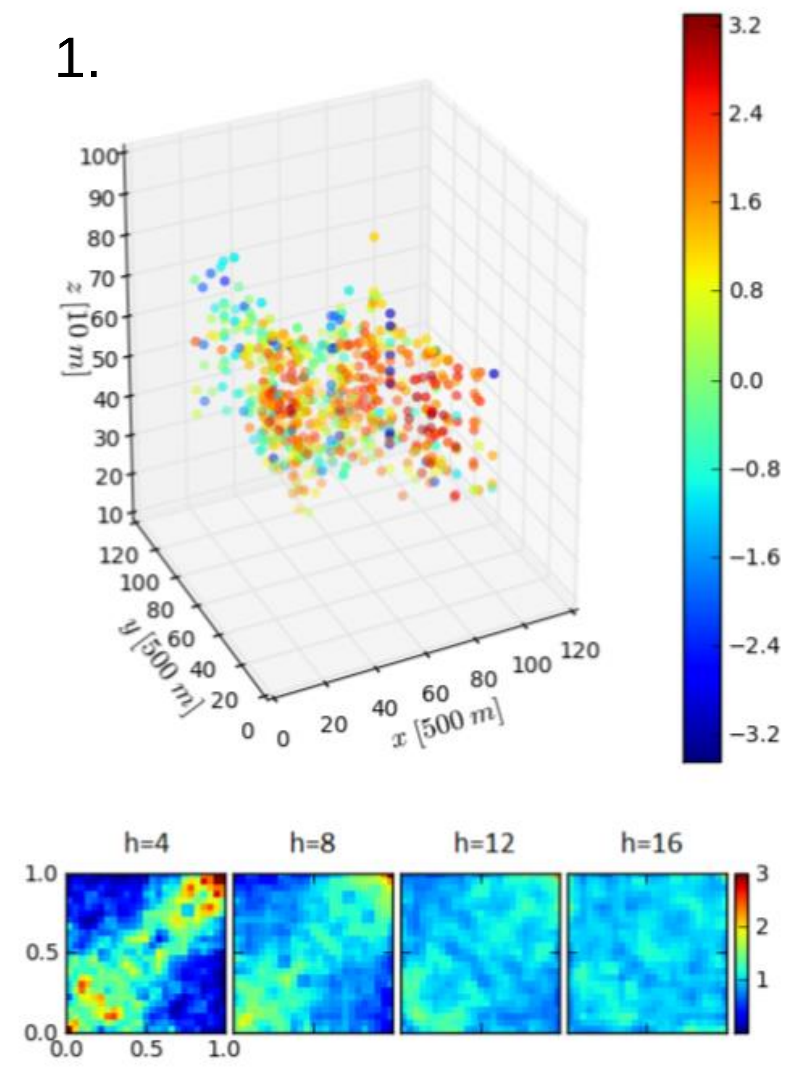

Fig2: Empirical copulas (lower) according to data (upper)

1. Analyse the data using empirical copulas
2. Fit theoretical copulas to the empirical copulas using Maximum likelihood
3. Use the fitted copula as spatial random function for the subsequent geostatistical simulations
4. Use the simulated realizations as input for flow simulations

2.

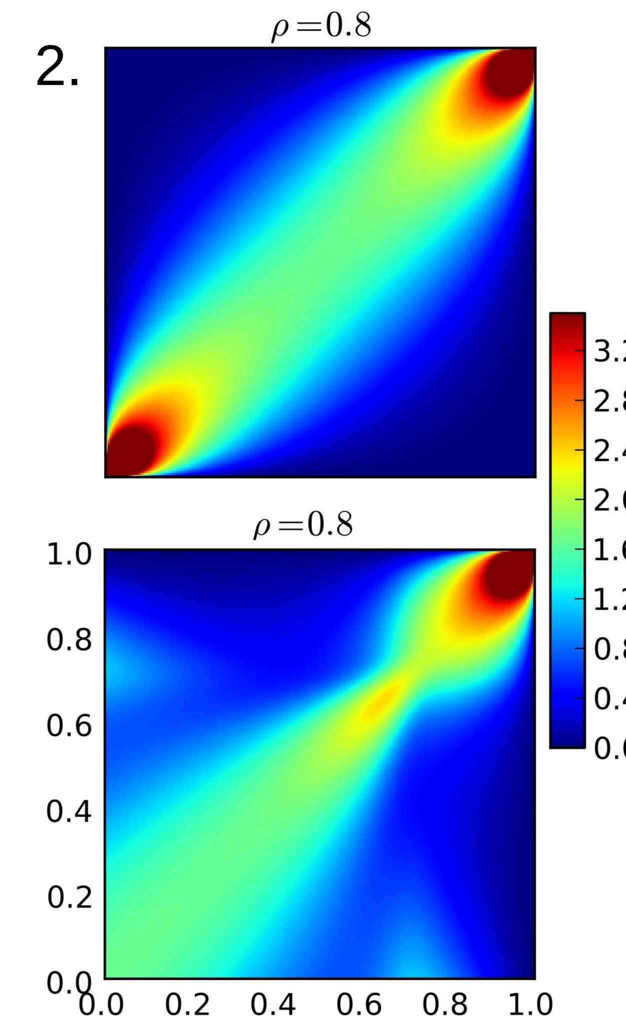

Fig3: Theoretical copulas

3.

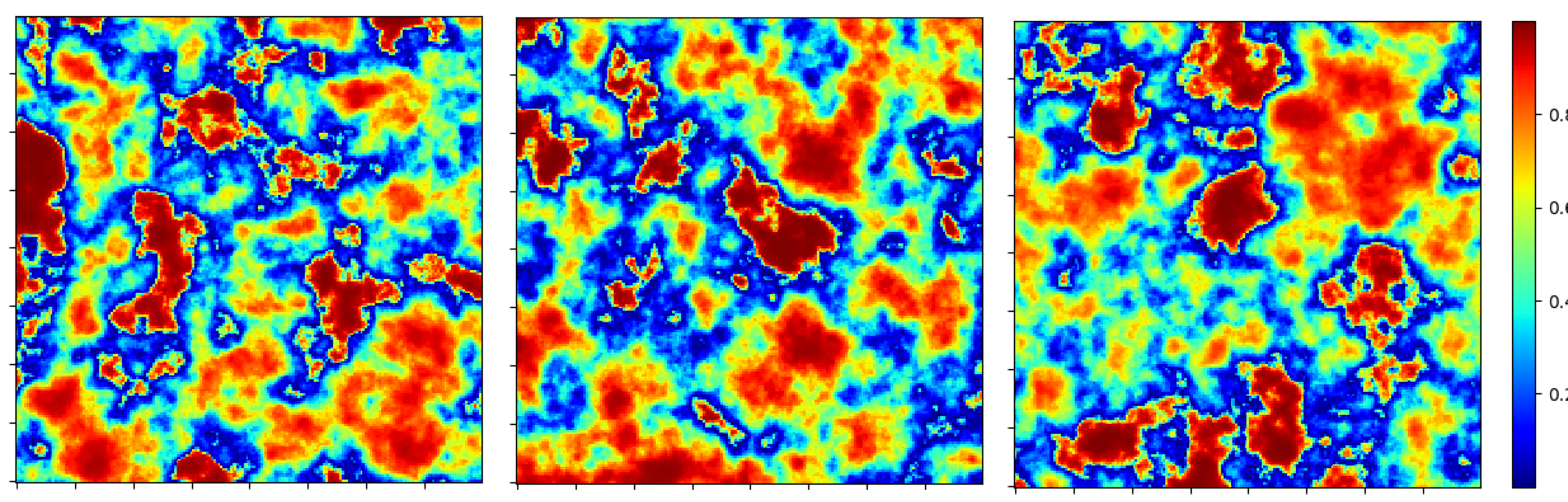

Fig4: Non-Gaussian spatial random fields with connected extreme values

WHY / PURPOSE

Analysis of different data sets shows that the Gaussian assumptions (symmetry in space) are rarely fulfilled in nature. Thus trying to model a variable which exhibits a non-Gaussian spatial dependence with a Gaussian approach will lead to an incorrect representation of the system of interest. This incorrect representation will also have an impact on dependent variables such as flow behaviour which could lead to poor predictions of e.g. production rates. Multiple point statistics (MPS) are frequently applied to model non-Gaussian spatial dependence structures. The main drawback of MPS however is the necessity for a suitable training image which is difficult to obtain in subsurface conditions. Therefore an approach that goes beyond the Gaussian assumptions and uses statistical inference instead of training images would be beneficial. One such approach is to use spatial copulas as spatial random functions.

RESULTS / BENEFITS to INDUSTRY

In order to analyse the impact of different geostatistical techniques on resource volumes and flow behaviour a systematic synthetic case study was carried out. The simplest case is shown here. A single well model was set up and all parameters except for the permeability are assumed to be known. The spatial distribution of permeability is then simulated using Gaussian and non-Gaussian common random fields (which are not distinguishable be traditional measures of dependence). These permeability fields are subsequently used as input for GEM and the resulting water and gas production was investigated. For the single well models the differences in the mean across the 100 realizations are rather small while the differences in the variances are significant. This indicates that if using Gaussian techniques only the variability in production rates could easily be underestimated. This effect becomes even more apparent when using multi well models and if several parameters are assumed to be unknown.

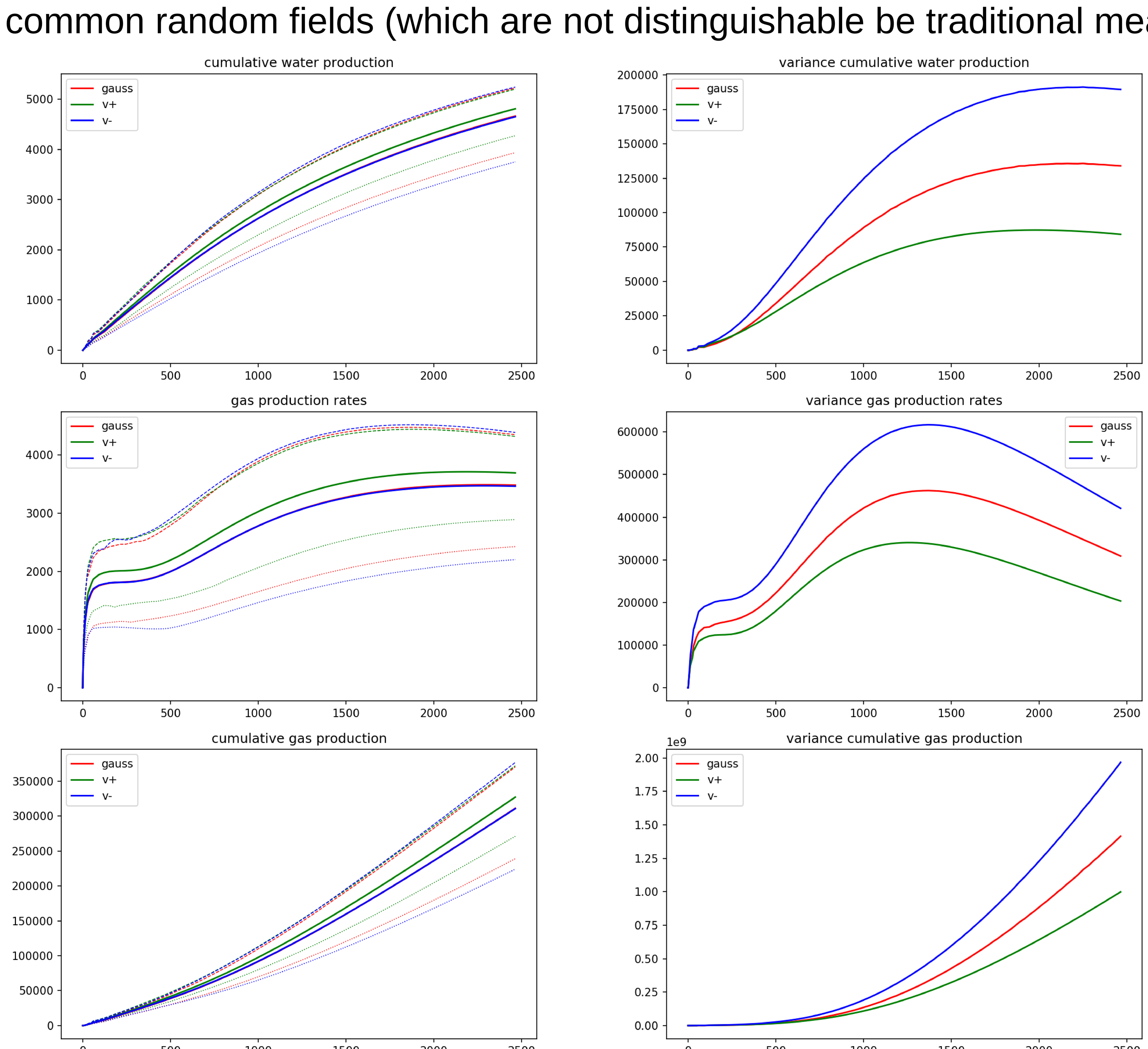

Fig5: Means and 95% confidence intervals (left) across 100 realizations, variances (right) across 100 realizations

CITATIONS: Bárdossy, A. (2006), Copula-based geostatistical models for groundwater quality parameters.,Water Resources Research, 42(W11416), doi:10.1029/2005WR004,754