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Random spatial processes and geostatistical models for soil variables

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Geostatistical models of soil variation have been used to considerable effect to facilitate efficient and powerful prediction of soil properties at unsampled sites or over partially sampled regions. Geostatistical models can also be used to investigate the scaling behaviour of soil process models, to design sampling strategies and to account for spatial dependence in the random effects of linear mixed models for spatial variables. However, most geostatistical models (variograms) are selected for reasons of mathematical convenience (in particular, to ensure positive definiteness of the corresponding variables). They assume some underlying spatial mathematical operator which may give a good description of observed variation of the soil, but which may not relate in any clear way to the processes that we know give rise to that observed variation in the real world.

In this paper I shall argue that soil scientists should pay closer attention to the underlying operators in geostatistical models, with a view to identifying, where ever possible, operators that reflect our knowledge of processes in the soil. I shall illustrate how this can be done in the case of two problems.

The first exemplar problem is the definition of operators to represent statistically processes in which the soil landscape is divided into *discrete domains*. This may occur at disparate scales from the landscape (outcrops, catchments, fields with different landuse) to the soil core (aggregates, rhizospheres). The operators that underly standard geostatistical models of soil variation typically describe continuous variation, and so do not offer any way to incorporate information on processes which occur in discrete domains. I shall present the Poisson Voronoi Tessellation as an alternative spatial operator, examine its corresponding variogram, and apply these to some real data.

The second exemplar problem arises from different operators that are equifinal with respect to the variograms of the corresponding spatial variables. Conventional geostatistical models are based on two-point statistics, and so only capture those features of spatial variation in n observations that are represented by the $\frac{1}{2}\left(n^2 - n\right)$ pairwise covariances. It is known that two-point geostatistics will not identify all the structure in a random spatial field. For example, connnectivity of regions with distinctive values of a variable, potentially very influential on scaling behaviour, are not described. I shall show how multipoint geostatistics can distinguish realizations of spatial processes with identical variogram functions, and explore the implications for the statistical description of scaling behaviour of process models.