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How to qualify and quantify directional dependencies in spatial random fields: Direction-dependent asymmetry

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Traditional geostatistical analysis is mainly based on variograms and/or covariance functions. A more advanced investigation of spatially distributed variables can be performed using rank order geostatistical methods. For example the rank correlation function in combination with the asymmetry function gives a more detailed insight in the spatial dependence structure of the data of interest. However, many physical processes, for example advection of solute in porous media, can lead to asymmetries that exhibit a certain direction, i.e. they lead to irreversibility in a spatial context. Reversibility is well known in time series analysis; however it is hardly utilized in geostatistics. Spatial reversibility or directional dependencies can neither be covered by the rank correlation function nor by the classical asymmetry function.
Therefore, a statistical test based on a chi-squared test on empirical directional copulas will be introduced that enables testing for spatial reversibility. In order to quantify the strength of directional dependencies a new direction-dependent asymmetry function is introduced. Different examples, ranging from synthetical flow and transport experiments to real-world precipitation data, will be used to demonstrate the applicability of the test and the new measure. The difference to classical anisotropy will be shown and the chi-squared test will also be used to test for significance.