Quantification of connectivity in ERT images based on Euler-Poincaré-characteristic

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Flow processes in the heterogeneous subsurface are controlled by the spatial distribution of regions with contrasting hydraulic (water flow) or thermal properties (heat flow). The dynamics of water and heat flow are not only controlled by the amount of conductive regions but by their connectivity as well to ensure that the processes are not obstructed by regions with low conductivity. The quantification of structure connectivity and its preservation in the inversion of ERT images is therefore required for modelling flow and transport. In addition to the percolation threshold (defining the critical electrical conductivity value that must be exceeded to form continuous structures across the boundaries of the system), the Euler-Poincaré-characteristic (EPC) can be used to quantify the connectivity of the subsurface. The EPC is a topological measure defined by the numbers of vertices, edges, and faces (in 3D) of a geometric figure. In binary images, the EPC is the number of disconnected regions of interest minus the number of holes in these regions. The EPC is high for systems with many disconnected regions and becomes negative for a highly connected network (a single structure with many holes). In contrast to percolation thresholds that must be calculated by testing the occurrence of structures spanning the entire system (requiring a 'global' analysis of the system), the EPC can be calculated easily as sum of local attributes (number of edges and vertices). To apply EPC in ERT images, a resistivity threshold ω is applied to separate more conductive regions with lower resistivity values from less conductive regions. By changing the threshold systematically from small to large values, the EPC as function of resistivity value EPC(ω) is obtained. The objective of the presentation is to introduce the EPC with illustrative examples and to apply it for a series of measured and synthetic ERT images. We will discuss the added value of EPC(ω) as descriptor of conductivity patterns and show the sensitivity of the EPC as function of parameter values and electrode arrays in the inversion process.