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Visualization of uncertainty in 3D stochastic voxel models of the Netherlands

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The Geological Survey of the Netherlands (GSN) systematically produces 3D stochastic voxel models of the upper 50 m of the subsurface. Each voxel contains the following properties: (1) the geological unit the voxel belongs to; (2) the lithological class (including grain-size classes for sand) that is representative for the voxel; and (3) a set of probabilities of occurrence for each of the lithological classes that may be present in the voxel.

The probabilities of occurrence provide us with a measure of model uncertainty. The probabilities of an individual voxel can be displayed in a single bar graph, thus showing its probability distribution and hence model uncertainty. Similar displays are possible in visualizations of virtual boreholes (i.e. vertical stacks of voxels). However in 2D visualizations, for instance a vertical cross-sections, it is no longer possible to show all probabilities in a single view: the user will always be presented with one of the probabilities at a time.

To solve this problem, Wellmann & Regenauer-Lieb (2012) proposed to use information entropy as a measure of uncertainty in 3D models. The information entropy of a voxel is a single value ranging from 0 to 1 that can easily be calculated from each of the probabilities of lithological class. An entropy value of 0 means that there is no uncertainty, whereas a value of 1 occurs when all lithological classes have the same probability. Values in between 0 and 1 account for both the number of lithological classes with a probability higher than 0 (the more classes, the higher the entropy) and the differences amongst the probabilities (the greater the differences, the lower the entropy).

Another approach to visualizing uncertainty is to use borehole density. Many users assume a one-to-one relationship between borehole density and reliability of the model. Although this relationship not always exists (for example, a homogeneous unit may be fully characterized by a single borehole), it adheres to common sense and is therefore easily understood. Borehole density was calculated for horizontal slices through the model, each at a certain height with respect to Dutch Ordnance Datum. For each of these horizontal slices, we used standard 2D GIS logic to count the number of boreholes available in cells of 5 by 5 km at the depth of the slice. The result was then converted to the voxel model.

The uncertainty measures described above are or will be disseminated through our webportal (www.dinoloket.nl) in a number of ways, including an on-line map viewer with the option to create virtual boreholes and vertical cross-sections, a series of downloadable GIS products and datasets to be used in the freely available 3D SubsurfaceViewer software.