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Insights into data-driven tectonic regionalisation in seismic hazard analysis

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In seismic hazard analysis, it is frequently assumed that specific assumptions relating to the modelling of ground motion and the characterisation of the seismogenic sources may apply to regions of the globe displaying similar tectonic characteristics. This process, called regionalisation, is frequently an essential component of a seismic hazard analysis either because local data is insufficient to characterise fully the source and propagation-path characteristics or because it is necessary to organise the information into few big categories considered homogeneous from a tectonic point of view. Examples of this operation can be found in methods and studies performed for the selection and the application of ground motion prediction equations in probabilistic seismic hazard analysis, real-time hazard and loss estimates such as ShakeMap and, characterisation of earthquake recurrence and maximum magnitude (Mmax) in low seismicity regions. A key concept that is common to all these analyses is the definition of tectonic similarity and, therefore, of the criteria adopted for the definition of ‘tectonically uniform’ areas. However, previous regionalisation works, have mainly been created by subjective judgements, thus, the process for the delineation of zones remains hardly reproducible. Clearly this makes difficult updating, reviewing and replicating regionalisation results across the globe.
These drawbacks can be overcome with the use of more objective and replicable data-driven methodologies for defining tectonic regions using global seismotectonic information. The regionalisation process can be implemented in an automatic computational scheme which is reproducible, comprehensible from a geophysical rationale, and capable of revision or refinement when new data is introduced database. However, tectonic regionalisation in seismic hazard, as in many other problems in earth system science, is a complicated problem, owing to the variety of parameters and uncertainty as well as to the vague definition of the ‘tectonic homogeneity’.
In this work we test a classification-scheme based on fuzzy logic that allows dealing concepts that are approximate rather than precise;. Since it is able to quantify and manipulate uncertainty with mathematical rigour, it represents a suitable, feasible and effective tool to deal with tectonic regionalisation issues. Moreover, it supports the incorporation of the expert judgement into the classification process (e.g., with higher seismic moment and lower quality factor, it suggests a higher degree of belief to be a tectonic active region). The proposed regionalisation methodology accounts for uncertainty by assigning to each point within the classified area a membership degree to the tectonic regions considered; this result can be incorporated into logic-tree models, a widely used tool for quantification of epistemic uncertainties in probabilistic seismic hazard assessment.
We describe a global tectonic regionalisation model for use in seismic hazard applications using a data-driven fuzzy regionalization methodology that largely relies on global seismotectonic databases and models (e.g., seismic moment rate, quality factor, shear-wave velocity), and its potential application.

Keywords: seismic hazard, regionalisation, fuzzy logic