HIERARCHICAL MATRICES (H-MATRICES) IN EARTHQUAKE CYCLE SIMULATIONS - APPLICATION TO PSHA

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Earthquake cycle simulations recreate the seismic cycle (with inter-, co-, and post-seismic phases), providing a virtual “sand box” to investigate how different model parameter influence earthquake rupture (sequences). The potentially complex fault geometries along which earthquakes may occur, are sub-divided into many fault elements where each element may rupture individually or as part of a larger, cascading earthquake. That said, fault element numbers can quickly reach levels that make earthquake cycle simulations prohibitively expensive - even for computationally cheap boundary element codes - especially when aiming to simulate long earthquake catalogs with a wide magnitude range on a large fault system. Increasing the versatility/performance of earthquake cycle simulations therefore requires reducing model complexity from its native N^2 scaling.

Since initial publication of our earthquake cycle simulator MCQsim (Zielke and Mai, 2023; BSSA) I incorporated the concept of H-matrices, substantially reducing the program’s memory requirements (e.g., size of stiffness matrix Kh_{ij}). Additionally, I further optimized when/how Kh_{ij} is accessed, increasing computational efficiency (i.e., not only memory requirements) for small AND large earthquakes.

Here, I provide technical details on how the H-matrix concept was incorporated and how it improved our simulations. I provide scaling tests to quantify the performance increase. Further, I showcase simulation results (i.e., earthquake sequences) for the Gulf of Aqaba and East Anatolian Fault systems, along with the workflow to incorporate them (the earthquake catalogs) into a probabilistic seismic hazard engine (namely OpenQuake).