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Physics-based constraints for probabilistic seismic hazard assessment in Húsavîk–Flatey fault zone, Northern Iceland

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Probabilistic seismic hazard assessment (PSHA) is widely used to generate national seismic hazard maps, design building codes for earthquake resilient structures, determine earthquake insurance rates, and in general for the management of seismic risk. However, standard PSHA is generally based on empirical, time-independent assumptions that are simplified and not based on earthquake physics. Physics-based numerical models such as dynamic rupture simulations account for the non-linear coupling of source, path and site effects, which can be significant in their respective contributions depending on the generally complex geological environment (e.g., Wollherr et al., 2019), and could potentially complement standard PSHA. In this study we demonstrate the benefits of such an approach by modeling various rupture scenarios in the complex Húsavík–Flatey fault zone (HFFZ), Northern Iceland. The HFFZ consists of multiple right-lateral strike slip segments distributed across ~100 km. The moment accumulated on the HFF since the last major earthquake in 1872 can result in an earthquake of magnitude 6.8 to 7 (Metzger and Jonsson, 2014) posing a high risk to Húsavîk's community, flourishing tourism and heavy industry.

We perform high-resolution 3D dynamic rupture simulations using the open-source software SeisSol (www.seissol.org), which can efficiently model spontaneous earthquake rupture across complex fault networks and seismic wave propagation with high order accuracy in space and time. Our models incorporate regional topography, bathymetry, 3D subsurface structure and varying models of the complex fault network while accounting for off-fault damage.

Synthetic ground motions suggest highly heterogenous radiation patterns and intense localization of shaking in the vicinity of geometric complexities, such as fault bends or rupture transition between segments. In our models, the hypocenter location does not affect the plausible moment magnitude of large events. However, changes in rupture directivity affect the spatial distribution of ground motion significantly. We run hundreds of dynamic rupture scenarios to generate a physics-based dynamic earthquake catalog of mechanically plausible events. Based on this, we identify a possible maximum magnitude earthquake and generate model-based ground motion prediction equations to complement standard empirical ground motion models. In addition, we use the open-

source python code SHERIFs (Chartier et al., 2019) to estimate the likelihood of each rupture event, which is mainly constrained by the fault slip rate estimated and fault-to-fault (f2f) rupture scenarios that are determined by the dynamic simulations. Finally, combining the fault seismic rates and the f2f probabilities with dynamic rupture scenarios and the OpenQuake framework allows us to perform physics-based PSHA for the HFFZ, the largest strike-slip fault in Iceland.