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Physics-based earthquake-tsunami modelling of the Húsavîk-Flatey transform fault zone in North Iceland

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The ~100 km long Húsavík Flatey Fault Zone (HFFZ) in North Iceland is the largest linear transform fault zone in Iceland composed of multiple fault segments that localise both strike-slip and normal movements, agreeing with a transtensional deformation pattern (Garcia and Dhont, 2005). With maximum seismogenic potential larger than Mw 7 and located primarily offshore, the HFFZ subjects several nearby coastal communities to potentially significant tsunami hazard from strong earthquake occurrence on the HFFZ. Namely, tsunami hazard assessment of submarine strike-slip fault systems in transtensional tectonic settings worldwide has received increased attention since the unexpected and devastating local tsunami in the Palu Bay following the 2018 Mw 7.5 Sulawesi earthquake in Indonesia.

Our goal is to carry out a physics-based assessment of the tsunami potential of the HFFZ using both a one-way linked dynamic earthquake rupture and shallow water equations tsunami workflow (Madden et al., 2021) as well as a fully-coupled elastic-acoustic earthquake-tsunami simulation (Krenz et al., SC 2021). We start by simulating physics-based dynamic rupture models with varying hypocenter locations with SeisSol (https://github.com/SeisSol/SeisSol), a scientific open-source software for 3D dynamic earthquake rupture simulation (www.seissol.org). SeisSol, a flagship code of the ChEESE project (https://cheese-coe.eu) and part of the project TEAR (https://www.tear-erc.eu), enables us to explore newly inferred simple and complex fault geometries that have been compiled and proposed in the ChEESE project by using unstructured tetrahedral meshes. The linked workflow uses the time-dependent seafloor displacement output from SeisSol to initialise bathymetry perturbations within sam(oa)²-flash. The dynamically adaptive, parallel software sam(oa)²-flash (https://gitlab.lrz.de/samoa/samoa) solves the hydrostatic shallow water equations (Meister, 2016). Here we consider the contribution of the horizontal ground deformation of realistic bathymetry to the vertical displacement following Tanioka and Satake (1996). Our second approach is based on the recent development of SeisSol which allows us to include a water layer in the earthquake-tsunami simulation to account for fully-coupled 3D elastic, acoustic and tsunami wave generation and propagation simultaneously.

The HFFZ is exposed to a laterally homogeneous regional stress field constrained from seismo-

tectonic observations, knowledge of fault fluid pressurisation, and the Mohr-Coulomb theory of frictional failure. We are able to model large Mw 6.7 to 7.3 dynamic rupture scenarios that can generate up to 2m of vertical coseismic offset. Our simulations are controlled by spontaneous fault interaction in terms of dynamic and static stress transfer and rupture jumping across the complex fault network. The models show a dynamic rake rotation of ±20° near the surface, indicating the presence of dip-slip components. Shallow fault slip of up to 8m and off-fault plastic yielding contribute to the tsunami genesis. The sea surface height anomaly (ssha), which is measured at synthetic tide gauge stations along the coastline and defined as the deviation from the mean sea level, provides an estimate about the impact of the tsunami. Our physically informed worst-case tsunami simulation causes a total ssha amplitude of ~1m. We conclude that the HFFZ has the capability to generate localised tsunamigenic earthquakes potentially posing significant hazards to the coastline communities.