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3D Gravity modeling of the volcanic island of Surtsey, Iceland

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The formation of the oceanic island Surtsey in the shallow ocean off the south coast of Iceland in 1963-1967 remains one of the best-studied examples of basaltic emergent volcanism to date. The island was built by both explosive, phreatomagmatic phases and by effusive activity forming lava shields covering parts of the explosively formed tuff cones. Constraints on the subsurface structure of Surtsey achieved mainly based on the documented evolution during eruption and from drill cores in 1979 and in the ICDP-supported SUSTAIN drilling expedition in 2017(an inclined hole, directed 35° from the vertical). The 2017 drilling confirmed the existence of a diatreme, cut into the sedimentary pre-eruption seafloor (Jackson et al., 2019).

We use 3D-gravity modeling, constrained by the stratigraphy from the drillholes to study the structure of the island and the underlying diatreme. Detailed gravity data were obtained on Surtsey in July 2014 with a gravity station spacing of ~100 m. Density measurements for the seafloor sedimentary and tephra samples of the surface were carried out using the ASTM1 protocol. By comparing the results with specific gravity measurements of cores from drillhole in 2017, a density contrast of about 200 kg m^{-3} was found between the lapilli tuffs of the diatreme and the seafloor sediments. Our approach is to divide the island into four main units of distinct density: (1) tuffs above sea level, (2) tuffs below sea level, (3) lavas above sea level, and (4) a lava delta below sea level, composed of breccias over which the lava advanced during the effusive eruption. The boundaries between the bodies are defined from the eruption history and mapping done during the eruption, aided by the drill cores.

A complete Bouguer anomaly map is obtained by calculating a total terrain correction by applying the Nagy formula to dense DEMs (5 m spacing out to 1.2 km from station, 200 m spacing between 1.2 km and 50 km) of both island topography and ocean bathymetry. Through the application of both forward and inverse modeling, using the GM-SYS 3D software, the results provide a 3-D model of the island itself, as well as constraints on diatreme shape and depth.