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Seismic attenuation due to wave-induced fluid flow in heterogeneous rocks containing fractures

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When a seismic wave travels through a fluid-saturated porous rock that contains heterogeneities in the mesoscopic scale range, that is, heterogeneities that are much larger than the typical pore size but much smaller than the predominant seismic wavelengths, local gradients in the pore fluid pressure arise. These fluid pressure gradients, which are due to the uneven response of the heterogeneities to the stresses associated with the passing seismic wavefield, induce viscous fluid flow and thus energy dissipation through internal friction. Due to the large compressibility contrast typically observed between fractures and their embedding background, fractured rocks represent a particularly prominent scenario where attenuation due to wave-induced fluid flow (WIFF) is expected to be predominant.

In some cases, the backgrounds of fractured rocks are highly heterogeneous. In particular, it is well known that permeability can vary orders of magnitude in relatively short distances, thus affecting the oscillatory fluid flow between the fractures and the background in response to the propagation of a seismic wave. Even though these features are expected to significantly modify the seismic responses of such media, this topic remains, as far as the authors know, largely unexplored in the literature. In this work, we apply numerical oscillatory relaxation tests based on the quasi-static poroelastic equations to study seismic attenuation and velocity dispersion in heterogeneous fluid-saturated porous rocks containing fractures. The fractures are modelled as very thin, highly compliant and highly permeable layers embedded in a stiffer and less permeable background. We perform an exhaustive sensitivity analysis to understand how the presence of heterogeneities in the embedding background modifies the seismic response of the probed medium. In particular, we analyze the influence of different heterogeneous permeability fields in these WIFF effects. This kind of study may have important implications with regard to the estimation of effective hydraulic properties from seismic data.