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Do seismic waves and fluid flow sense the same permeability in fluid-saturated porous rocks?

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Wave-induced flow due to the the presence of mesoscopic heterogeneities, that is, heterogeneities that are larger than the pore size but smaller than the prevailing seismic wavelengths, represents an important seismic attenuation mechanism in fluid-saturated porous rocks. In this context, it is known that in the presence of strong permeability fluctuations, there is a discrepancy between the effective flow permeability and the effective seismic permeability, that is, the effective permeability controlling seismic attenuation due to wave-induced fluid flow. While this subject has been analyzed for the case of random 1D media, the corresponding 2D and 3D cases remain unexplored, mainly due to the fact that, as opposed to the 1D case, there is no simple expression for the effective flow permeability. In this work we seek to address this problem through the numerical analysis of 2D rock samples having strong permeability fluctuations. In order to do so, we employ a numerical oscillatory compressibility test to determine attenuation and velocity dispersion due to wave-induced fluid flow in these kinds of media and compare the responses with those obtained by replacing the heterogeneous permeability field by homogeneous fields, with permeability values given by the average permeability as well as the effective flow permeability of the sample. The latter is estimated in a separate upscaling procedure by solving the steady-state flow equation in the rock sample under study. Numerical experiments let us verify that the attenuation levels are less significant and the attenuation peak gets broader in the presence of such strong permeability fluctuations. Moreover, we observe that for very low frequencies the effective seismic permeability is similar to the effective flow permeability, while for very high frequencies it approaches the arithmetic average of the permeability field.