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Estimation of the 3D correlation structure of an alluvial aquifer from surface-based multi-frequency GPR data

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Knowledge about the heterogeneity in subsurface hydraulic properties is critical for aquifer characterization and the corresponding prediction of groundwater flow and contaminant transport. Whereas the vertical correlation structure of the heterogeneity is often constrained by borehole information, the lateral correlation structure is generally unknown because the spacing between boreholes is too large to allow for a meaningful interpolation. There is, however, evidence to suggest that the latter information may be extracted from the correlation statistics of the subsurface reflectivity structure imaged by surface-based ground-penetrating radar (GPR) measurements. To date, case studies using this approach were limited to 2D profiles acquired at a single antenna center frequency in areas with limited complementary information. As a result, the practical reliability of this methodology has been difficult to assess. To overcome this limitation, we extend previous work to 3D GPR data acquired using two antenna center frequencies at the extensively explored and well constrained Boise Hydrogeophysical Research Site. We find that the results obtained using the two frequencies are fully consistent and in agreement with the vast information from complementary studies available for this site. Contrary to previous 2D work, our results also indicate that the reflectivity of surface-based GPR data is not only sensitive to the aspect ratio of the heterogeneity, but also, albeit to a lesser extent, to the so-called Hurst number, which is a key parameter characterizing the complexity of the fine-scale structure.