Subsurface water flow detection by time-lapse reflection GPR data

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Understanding subsurface water flow is important as it e.g. controls contaminant transport, has an impact on the amount of aquifer recharge, and can be used for storm water management purposes. However, there do not exist many methods that can observe the water flow in the field. Furthermore, the flow patterns can be very diverse due to the complex geological conditions, e.g. faults, fractures, and heterogeneous permeability of the subsurface formations. In order to map the subsurface water flow in a chalk formation, we performed a water injection experiment in the Rørdal Quarry, Northeast Denmark. A total water volume of 700 liters was injected via a 50 cm deep hole within 8 hours. Around the injection hole, we conducted time-lapse GPR measurements along 6 inlines and 6 crosslines. Seven measurements campaigns were performed over an eight-hour time period. We analyze the time-lapse GPR reflection sections in order to investigate the variations of the different measurements. Initially, we subtract the repeated measurements and baseline measurements, which shows that some survey lines have clear changes after water injection, while others only show very small or no changes. To verify the differences, we pick travel times of selected horizons in the time-lapse data and compare them (cf. Truss et al., 2007; Allroggen et al., 2015). This analysis highlights the travel time variations imposed by the injected water. Moreover, we perform correlation analysis of the measurements before and after water injection. The correlation coefficients show relatively small values on the lines that exhibit clear differences, further confirming the differences caused by the water infiltration. Initial integrated analysis of the different results shows that the water mainly flows towards the southeast from the injection hole. This is consistent with the orientation of the fracture system observed in the reflection GPR profiles, indicating that the water flow is primarily controlled by the fractures.
