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4D ground penetrating radar measurements as non-invasive means for hydrological process investigation

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The missing vision into the subsurface appears to be a major limiting factor for our hydrological process understanding and theory development. Today, hydrology-related sciences have collected tremendous evidence for soils acting as drainage network and retention stores simultaneously in structured and self-organising domains. However, our present observation technology relies mainly on point-scale sensors, which integrate over a volume of unknown structures and is blind for their distribution. Although heterogeneity is acknowledged at all scales, it is rarely seen as inherent system property. At small scales (soil moisture probe) and at large scales (neutron probe) our measurements leave quite some ambiguity. Consequently, spatially and temporally continuous measurement of soil water states is essential for advancing our understanding and development of subsurface process theories.

We present results from several irrigation experiments accompanied by 2D and 3D time-lapse GPR for the development of a novel technique to visualise and quantify water dynamics in the subsurface. Through the comparison of TDR, tracer and gravimetric measurement of soil moisture it becomes apparent that all sensor-based techniques are capable to record temporal dynamics, but are challenged to precisely quantify the measurements and to extrapolate them in space. At the same time excavative methods are very limited in temporal and spatial resolution. The application of non-invasive 4D GPR measurements complements the existing techniques and reveals structural and temporal dynamics simultaneously. By consequently increasing the density of the GPR data recordings in time and space, we find means to process the data also in the time-dimension. This opens ways to quantitatively analyse soil water dynamics in complex settings.