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Near-Surface Time-Lapse and Polarization Surveying at Field Sites with Precision 3D GPR

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Repeated high-resolution 3D Ground Penetrating Radar (GPR) surveying can enhance near-surface characterization in two ways: Firstly, time-lapse imaging monitors changes of fluid content over time. Secondly, surveying the same area with different antenna orientations exploits polarization effects of buried targets. Theory, synthetic modeling and lab experiments have shown promise to non-invasively yield in-situ hydrologic parameters and rock properties. However results from realistic field conditions are still a rarity. Field sites in excess of 100 m^2 and surface irregularities make efficient acquisition of precisely repeatable surveys with standard GPR equipment a challenge. To overcome this bottleneck we have integrated GPR with Rotary Laser Positioning. With 20 x,y,z coordinate updates per second, continuously moving GPR antennae can be tracked centimeter precise. A real-time LED guidance system shows the GPR antenna operator how to follow pre-computed survey tracks. Portability of all equipment and the possibility to change the GPR antenna allow adaptation to a wide range of field sites. Two field data examples confirm the feasibility and precision of such repeated 3D GPR surveying. Comparing data acquired after wet summer and dry winter conditions shows time-shifts up to 20 ns caused by the change of water content in the vadose zone. Based on GPR time-shift extraction, volumetric water content changes are computed for the entire soil and rock volume. The second survey example includes orthogonal 250 MHz imaging of both anthropogenic and sedimentary structures. Subtraction of the two 3D surveys acquired with a 90 degree rotation of the GPR antenna enhances point targets, pipes, and foundations while geological reflectors are subdued. Polarization facilitates discrimination of anthropogenic targets from geological background. These first results show how field-based time-lapse and polarization GPR is now a reality and promises similar breakthroughs achieved with the invent of seismic time-lapse and multi-component surveying.