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Ultra-high resolution four-dimensional surface-change measurements using ground-based Tripod LiDAR for earthquake, debris flow, and spatially varied snow-depth analysis

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Ground-based tripod or terrestrial LiDAR (T-LiDAR) has the potential to significantly advance science and hazard assessments in a broad number of research disciplines using remotely collected ultra-high resolution and accurate ($\pm$4 mm) digital imagery of scanned targets. The imagery is acquired at distances from 3 to $>$800 m, depending on both the target's infrared reflective properties and the instrument. Scientific analysis of the ultra-high resolution T-LiDAR imagery includes the analysis of 3-D datasets to calculate target dimensions, volume, or area, and the time-series analysis of repeat imagery to evaluate volume change, target stability, or surface displacements.

Three examples are given that show a range of scientific T-LiDAR applications to change-detection and measurement research in earth science: (1) post-seismic slip distribution for the Magnitude 6.0 2004 Parkfield Earthquake on the San Andreas fault, California, USA; (2) quantitative assessment of post-fire debris-flow hazards; and (3) snow volume calculations in the central Sierra Nevada, California. T-LiDAR imagery was collected the day after the 29-Sept-2004 Parkfield Earthquake, and from the same vantage points 10, 23.5, and 41 weeks following the mainshock. A structural support for a bridge spanning the active trace of the fault near the epicenter moved 71 mm (right-lateral displacement) in the 10 weeks following the mainshock, and moved an additional 26 mm in the following 23.5 weeks. In the second example, T-LiDAR was used to collect 1.85 x 10^8 data points bracketing a 76 mm rainfall event in a recent burn

area with steep terrain to assess hillslope stability and debris-flow-hazard conditions. Differencing the pre- and post-rainfall imagery showed that centimeter and decimeter scale rilling was the primary transport process, with about 11 mm/m^2 of material removed near the ridgeline. In the third example, repeat T-LiDAR surveys were used to measure changing snow-surface heights at the U.C. Berkeley Central Sierra Snow Lab during the spring snowmelt of 2004. T-LiDAR-measured snow volumes were combined with snow-water equivalent measurements near the location of maximum snow depth, to compute an estimated 35.6 m^3 of water above two lysimeters that have a combined 37-m^2 footprint. The subsequent snowmelt pattern was very uniform across the snow lab in the subsequent 4 weeks, with about a 1-m decrease in snow depth, which equates to 7.2 m^3 of water.