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Application of pulse-Doppler radar and 3D LiDAR for high-resolution velocity measurements of three debris flows at Illgraben (Switzerland)

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The surface velocity of debris flows is constantly subject to strong temporal and spatial fluctuations. These are amplified by the pulse-like occurrence of surges throughout the event and by the high variance of the solids fraction. However, continuous information on velocities of multiple consecutive surges within a single debris-flow event with high temporal resolution is rare. In this study, we test a pulse-Doppler (PD) radar over a total torrent length of 180 m. The PD radar utilizes pulsed transmission and provides spatially resolved cells, called range gates, that extend over a width of 20 meters. Doppler velocity spectra composed of velocity classes and echo intensities are obtained at 4 Hz for each range gate. From these, we derived continuous velocity-time data sets. We present PD radar data for three debris flows that occurred on 05.06, 30.06, and 08.09.2022 at the Illgraben creek, Switzerland. The radar data were validated at the first event with a velocity data set obtained from a LiDAR scanner installed at the same location. This novel method collects high-resolution 3D point clouds at 10 Hz. This data was used to derive a high-resolution velocity vector field for one of the events. We isolate a ~ 2x2 m box in the middle of the channel and compare the LiDAR derived velocities at this location to those measured by the PD radar. Our comparison shows a strong correlation between the two data sets, with a coefficient of determination of 0.85. In addition, we note a minor consistent offset in the two velocity data sets of 0.5 m/s. We attribute this to the nature of the different measurement methods and conclude that the two methods may be sensitive to different features of the surface of the flow. However, our results show the high effectiveness and reliability of both methods in debris-flow monitoring. We anticipate that further analysis of the data sets will provide new insights into the geophysical principles of debris flows.