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High-density 3D and 4D GPR data acquisitions over alpine glaciers using a newly developed drone-based system.

Bastien Ruols, Ludovic Baron, and James Irving
Université de Lausanne - UNIL, Institut des sciences de la Terre - ISTE, Lausanne, Switzerland (bastien.ruols@unil.ch)

We have developed a drone-based GPR system at the University of Lausanne that allows for the safe and efficient acquisition of large, high-density, 3D and 4D datasets over alpine glaciers. The system is able to record approximately 4 line-km of high-quality GPR data per set of drone batteries in less than 30 minutes of operation which, combined with multiple sets of batteries and/or the possibility of charging at the field site, means that 3D datasets over a large area can be acquired with unprecedented efficiency. The latter performance is possible thanks to (i) a custom-made real-time-sampling GPR controller that has been specifically designed for glaciers studies, (ii) minimization of the total payload weight using custom-built antennas and carbon-fiber components, and (iii) development of an optimized survey methodology. Further, because the drone is equipped with real-time kinematic GPS positioning, survey paths can be repeated with great precision, which opens new opportunities in term of 4D data acquisitions.

In the summer of 2022, we acquired both 3D and 4D data over two Swiss glaciers. On the Otemma glacier, we surveyed a grid of 462 profiles representing a total length of 112 line-km of data in only four days. After 3D binning, the trace spacing intervals in the in-line and crossline directions were respectively 0.4 m and 1 m, making this arguably the largest 3D GPR dataset of such density ever recorded over ice. The interface between the ice and the bedrock, visible on all profiles, extends to 1000 ns which translates into a depth of approximately 80 m. In addition, internal englacial and subglacial 3D structures are clearly detectable.

In parallel, we visited the Rhône glacier on a monthly basis between June and September 2022. A collapse feature, identified by the presence of large circular crevasses, had formed and was evolving close to the snout of the glacier. This represented a great opportunity to test the 4D acquisition capabilities of our system. We collected four high-density 3D datasets on the same survey grid. The repeatability of the trajectories was excellent as the paths differ only by a few centimeters between occurrences. Clear variations in the internal structure of the glacier are visible which will be investigated in the upcoming months.