Drone-based GPR for high-density 3D and 4D acquisitions on alpine glaciers.

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Thanks to the excellent propagation characteristics of radar waves in ice, ground-penetrating radar (GPR) has served as a key geophysical method in the field of glaciology for more than half a century. Recently, a number of studies have demonstrated that high-density 3D GPR data, acquired on the glacier surface via a series of closely spaced, parallel survey lines, can serve extremely useful for the detailed investigation of alpine glacier internal structures. Such surveys are typically acquired on foot and are highly labor intensive and often dangerous. As a result, the extent of the area covered is usually limited, and surface features such as crevasses or moulins must be avoided. Recent advances in the development of uncrewed aerial vehicles (UAV) technologies motivate the acquisition of glacier GPR data by drone.

We have developed a drone-based GPR system for the safe and efficient acquisition of 3D data on alpine glaciers. Our GPR instrument uses real-time sampling to record traces having a fixed length of 2800 ns at a rate of 14 Hz. Each trace is stacked over 5000 times and acquired using a sampling frequency of 320 MHz. Our single lightweight transmit-receive antenna has a center frequency of 70 MHz. The optimized total weight of the payload is around 2 kg, and the system is equipped with a terrain following device which allows it to stay at an approximately constant height above the glacier surface. At a flight speed of 4 m/s and height of 5 m above the ice, the drone is able to record around 15 line-km of GPR data in less than 2 hours. The system is also compact enough to be transported by the operators on foot to the field site without the need for a helicopter.

Finally, the drone is equipped with real-time kinematic differential GPS, which allows the precise repetition of 3D GPR surveys with time. In the summer 2022, this technology has been used in the Swiss Alps to investigate glacier internal hydrology and dynamics, as well as the formation of near-surface collapse features. The objective is to repeat such 3D GPR data survey acquisitions on a regular basis over the span of a full year in order to gain new insights into the temporal variation of glacier internal structures.