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Best practices in field deployments for the seismic detection of snow avalanches

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Since the 1970s, it is known that seismic monitoring systems can be used for the remote detection of avalanches. Recent studies have shown that such systems are well suited to continuously monitor avalanche activity independent of weather conditions and up to distances of 30 kilometers. However, detection capabilities and performance strongly depend on the deployed instrumentation. In the past, various seismic systems and different geometries were used, including low-cost single sensor geophones, geophone arrays, three component seismometers and permanent broadband stations. Since none of these systems were deployed simultaneously, it remains unclear what the advantages and disadvantages are of the different systems and deployment strategies. For the last decade, we have worked on developing a geophone array for avalanche monitoring. Continuous seismic data recorded during five winter seasons with different array configurations and sensors allowed us to evaluate and optimize our deployment strategies. Based on these results, we can define recommendations for optimal array configuration for avalanche detection: (1) geophones with a low eigenfrequency should be used, as most energy of avalanche signals is below 10 Hz, (2) to suppress environmental noise and increase the signal-to-noise ratio, sensors should either be buried in the ground or attached to rocks or bedrock, and preferably covered by a thick homogenous snowpack, and (3) to improve array processing results, the maximum distance between the sensors of the array should be at least 100 m. During the 2017-2018 winter season, we also deployed four additional seismic systems, ranging from high-end broadband seismometers to low-cost seismic data acquisition systems, close to our geophone array. Several larger avalanches released in the vicinity of our field site, allowing us to characterize the advantages and disadvantages of the various seismic systems in terms of signal-to-noise ratio, avalanche type, size and distance. Results from this experiment showed that it is possible to detect large nearby avalanches with most of these systems. Smaller or more distant avalanches were only recorded by the three component broadband seismometers or our geophone array. Overall, we observed large differences in signal-to-noise ratio for the different systems. Furthermore, data quality of our one component geophone array is about as good as that of the seismometers. Low-cost seismic systems, on the other hand, should be used with caution, as the the signal-to-noise ratio was very low. Due to this and technical problems, one low-cost system even recorded almost no avalanches. Testing different seismic systems and array configurations for avalanche monitoring, we were able to determine their performance and restrictions. The results of these experiments should serve as recommendations for future deployments of such systems.