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Monitoring lake ice with seismic and acoustic sensors

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Seismic monitoring of the thickness and elastic parameters of floating ice on lakes and the sea is of interest in understanding the climate change impact on Alpine and Arctic environments, assessing ice safety for recreational and engineering purposes, studying ice shelves as well as exploring possibilities for the future exploration of the icy crusts of ocean worlds in our solar system. Seismic data can provide an alternative to remote-sensing and ground-based radar measurements for estimation of ice thickness in cases where radar techniques fail. Because of the difficult access to Alpine and Arctic environments as well as seismic sensor coupling issues in ice environments, it is of interest to optimize the use of seismic instruments in terms of sensor type, sensor numbers and layouts.

With the motivation to monitor over time the seismic activity of the lake ice and the ice properties, we conducted a series of seismic experiments on frozen lake St. Moritz in the Swiss Alps during two consecutive winters. Arrangements of sensors ranging in numbers from 96 geophones in mini-arrays to installations of 8, 2 and 1 conventional seismic sensors were used to measure the seismic wavefield generated by ice quakes (cryoseisms), artificial sources like hammer strokes, and ambient vibrations. These data provide an impressive and rich insights into the growth of the ice and variations of seismic activity with time. Even recordings with only a single station enable the determination of ice parameters and location of ice seismicity. Furthermore, we are exploring the value of recording air-coupled waves with microphones as alternative contact-free measurements related to seismic wave propagation in the ice, possibly even with sensors placed on the lake shore.