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A passive seismic approach including fiber-optic sensing for permafrost monitoring on Mt. Zugspitze (Germany)

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As observed elsewhere on a global scale, permafrost at Mt. Zugspitze (German/Austrian Alps) is warming in response to climate change. To monitor permafrost warming and thawing, which affect the rock slope stability and thus the hazard potential, borehole temperature logging and electrical resistivity tomography (ERT) have been employed at Mt. Zugspitze for more than a decade. Furthermore, a recent study shows that the ambient seismic noise recordings of a single seismometer at the same site can be utilized to track permafrost changes over the past 15 years. This passive seismic approach is non-invasive, labour- and cost-effective and provides high temporal resolution. Together with recent advances in instrumentation allowing the measurement of seismic vibrations on a meter scale along a fiber-optic cable (known as distributed acoustic sensing), passive seismology provides unprecedented spatio-temporal resolution for monitoring applications.

Starting in July 2021, we extended the single-station deployment on Mt. Zugspitze with three small seismic arrays (six stations each, aperture ~25 m) along the permafrost-affected ridge. The stations are partly installed in a tunnel beneath the surface, which intersects a permafrost body, thus allowing in-situ observations of the frozen rock. We equipped the tunnel facilities with a fiber-optic cable, which we will interrogate on a regular basis, about once per quarter year, to resolve seasonal permafrost dynamics. A first 10-day data set of this monitoring element with seismic channel spacing of 2 m along a cable exceeding 1 km in length is already available and shows that artificial avalanche triggering explosions were successfully recorded. We present data and first results dedicated to permafrost monitoring along the fiber-optic cable and between pairs of seismic stations through cross-correlation of ambient seismic noise. In addition, the seismic arrays are designed to derive rotational ground motions, which we expect to be more sensitive to local subsurface/permafrost changes compared to the classical translational motion measurements. The experiment aims to explore the permafrost monitoring capabilities of passive seismology compared to more classical and established methods as ERT.