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Active and passive seismic investigations in Alpine Permafrost at Hoher Sonnblick (Austria)

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Different geophysical measurements have been applied at the Hoher Sonnblick study area to gain information about permafrost distribution as well as heterogeneities controlling heat circulation, in the frame of the ÖAW-AtmoPerm project, which aims at the understanding the impacts of atmospheric extreme events on the thermal state of the active layer. Electrical Resistivity Tomography (ERT) has been widely accepted as a suitable method to characterize permafrost processes; however, limitations are imposed due to the challenges to inject high current densities in the frozen periods and the loss of resolution of electrical images at depth require the application of further geophysical methods. To overcome such problems, we investigate here the application of active and seismic methods. Seismic campaigns were performed using permanent borehole and temporarily installed surface geophones. A total of 15 borehole geophones are installed at depths of 1 m, 2 m, 5 m, 10 m and 20 m in three boreholes which are separated by a horizontal distance of 30 m between each other. Active measurements utilized 41 surface and 15 borehole geophones and a total of 199 excitation points. Surface geophones were laid out along two crossing lines with lengths of 92 m and 64 m, respectively. The longer line was placed directly along the borehole transect and the shorter one was oriented perpendicular to it. Hammer blows were performed with a spacing of 1 m inline the geophones and 4 m in crosslines rotated by 45 degrees, permitting 3D acquisition geometry. In addition to the active sources, data loggers connected to the borehole geophones permitted the collection of continuous 36-hours datasets for two different thermal conditions. Seismic ambient noise interferometry is applied to this data and aims at the identification of velocity changes in the subsurface related to seasonal changes of the active layer. A potential source of ambient seismic energy is the noise excited by hikers and the activity from the nearby cable cars station. Results obtained from the 3D-hammer seismics and interferometry are compared and benchmarked against each other. Changes in the seismic velocities in the subsurface permitted the delineation of the active layer and improved permafrost investigation when combined with ERT monitoring. Seismic results were then interpreted together with those obtained with ERT monitoring, electromagnetic induction (EMI) and ground-penetrating radar (GPR).