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Assessment of data fusion strategies with regard to an enhanced characterization of alpine permafrost

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Increasing temperatures and changing precipitation regimes in the Alps due to climate change are known triggers for the degradation of alpine permafrost. Hence, risk assessment of associated geohazards (e.g., rockfalls and rock avalanches) and conception of engineering projects in alpine regions require detailed knowledge about the present state as well as the spatio-temporal evolution of alpine permafrost. To overcome the spatial limitations of direct investigations (i.e., temperature measurements in boreholes), near-surface geophysical methods are well-established to obtain high resolution information regarding the distribution of alpine permafrost and temporal variations in the active layer thickness. However, for an improved interpretation taking into account different geophysical and wellbore data, joint analysis strategies are required. Although data fusion approaches are nowadays widely used in permafrost research, the associated limitations of the inversion algorithms and ambiguous processing results are seldom addressed. To this end, we performed an extensive numerical analysis on detailed conceptual subsurface models aiming at an improved understanding of refraction seismic tomography (RST), ground-penetrating radar (GPR) and electrical resistivity tomography (ERT) imaging results in an alpine permafrost environment. To facilitate the evaluation of different data fusion strategies, we implemented processing workflows in the open-source pyGIMLi framework (Geophysical Inversion and Modeling Library). Here we describe results obtained through numerical simulations and the analysis of real multi-method data sets acquired at Hoher Sonnblick (Austria) consisting of RST, GPR, ERT and borehole temperature measurements. Based on a statistical analysis of the obtained imaging results we assessed the performance of different data fusion strategies in terms of active layer delineation and ice content estimation.