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Quantifying thaw subsidence in a permafrost landscape (Bayelva basin, Svalbard)

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Rising temperatures have led to permafrost degradation throughout the Arctic. The melting of excess ground ice leads to a loss of structural support and consolidation of soils. As a consequence, the surface subsides, which, in turn, can accelerate further ground ice loss. Therefore, thaw subsidence is an important metric for monitoring permafrost degradation. With temperature rise reaching twice the Arctic and seven times the global average rate, warming trends in Svalbard are particularly high, leading to severe impacts on permafrost conditions. However, knowledge on subsurface permafrost changes in Svalbard is mostly limited to a few in situ observations. In this study, we aimed to spatially expand research on permafrost degradation by applying a multimethod approach to quantify thaw subsidence in the Bayelva basin (near Ny-Ålesund, Svalbard). First, during a field campaign in summer 2023, we measured Global Navigation Satellite System (GNSS) points and calculated elevation changes since an earlier GNSS survey in 2019. Second, we coregistered and differenced high-resolution digital elevation models (DEMs) for a period of more than 80 years (from 1936, 1995, 2008, 2010, 2019, and 2020) to identify spatial patterns of thaw subsidence over a larger area. Third, we analysed how thaw subsidence relates to various terrain attributes and land cover. By employing these methods, we clearly detected thaw subsidence in the Bayelva basin. The GNSS measurements showed a spatially averaged subsidence of 2.7 cm between 2019 and 2023. With DEM differencing, we observed annual surface subsidence in the order of metres for areas of glacial retreat, in the order of decimetres for moraines, and up to a few centimetres for tundra areas in the glacier foreland. We furthermore detected spatial variations in thaw subsidence throughout the tundra. We conclude that surface subsidence is an ongoing, widespread, and important process in Svalbard's permafrost landscapes. In this study, we demonstrate the challenges of DEM coregistration in areas with a lack of stable terrain. Nevertheless, our results highlight the potential of GNSS measurements and DEM differencing for quantifying thaw subsidence in the Arctic.