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The Evolution of the Snow Facies on the Greenland Ice Sheet Observed by the Last Decade of TanDEM-X Interferometric SAR Data

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Climate change and the resulting accelerating melt on the Greenland and Antarctic ice sheets are causing dramatic and irreversible changes at a global scale, significantly contributing to sea-level rise. In this scenario, monitoring the evolution of diagenetic snow facies can provide valuable insights to better comprehend climate-related variables and trends. Previous studies of the Greenland ice sheet led to the definition of four main snow facies, depending on the amount of snow melt and on the properties of the snow pack itself: the inner dry snow zone, where melt does not occur; the percolation zone, where a limited amount of melt per year occurs, leading to the generation of larger snow grains and the formation of small ice structures; the wet snow zone, where a substantial part of the snow melt drains off during summer and is characterized by the presence of multiple ice layers; and the outer ablation zone, where the previous year accumulation completely melts during summer, resulting in a surface of bare ice and surface moraine. By exploiting X-band TanDEM-X interferometric synthetic aperture radar (InSAR) acquisitions, previous works explored the idea of classifying different snow facies of the Greenland ice sheet utilizing an unsupervised machine learning clustering approach. The analysis was performed using data acquired in winter 2010/2011 only, under the assumption of stable climatic conditions and similar acquisition geometries. In this paper, we further investigate the evolution of the snow facies of Greenland throughout the last decade of TanDEM-X observations, proposing unsupervised machine learning strategies for snow facies characterization by using InSAR features such as backscatter, volume decorrelation, the incidence angle and height of ambiguity. We use TanDEM-X data acquired during the winter of 2010/2011, 2015/2016, 2016/2017, 2020/2021, and 2021/2022, where full or partial coverage of the Greenland ice sheet is available. The challenges and caveats of such approaches for different image acquisition geometries will be presented. Finally, the potential of TanDEM-X for investigating large-scale interannual changes in the dry snow zone over Greenland will be investigated as well.