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A new metric between vertical snow profiles using dynamic time warping

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A snow profile, i.e. the variation of snow physical properties as a function of depth, captures the snow cover stratigraphy which is crucial for many applications such as the assessment of the avalanche danger. With the increasing use of snowpack numerical models or electronic highly-resolved snow profilers (e.g. penetrometers) which generates a huge amount of data, there is a need for a robust and efficient method to compare and classify snow profiles. It has long been recognized (e.g. Lehning et al., 2001) that accounting for shifted layer position, i.e. layers at the same depth are not necessarily at the same position in the stratigraphic sequence, is crucial to obtain a meaningful metric. The main idea is to partition the difference between profiles into depth differences and differences of the considered intensive property. In this way, profiles that share the same crust or weak layer, but at different depths can be recognized as similar and only differ by the position of the common feature. In this work, we present a new metric between snow profiles based on dynamic time warping. On contrary to previous metrics, the associated layer matching is here bijective, preserves the order of the layers and is numerically very efficient. The new perspectives opened by this development will be illustrated on three instances : the clustering of large spatially-distributed snowpack simulations, the evaluation of snowpack models with observed snow profiles and the analysis of the spatial variability of measured hardness profiles.