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Quantifying spatio-temporal variability of soil water storage and their controls at multiple scales

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Soil water is the primary limiting factor in semiarid ecosystems and determinant of environmental health. The distribution of soil water in space and time has important hydrologic applications. However, the spatio-temporal variability of soil water is a major challenge in hydrology as their distribution in the landscape is controlled many factors and processes acting in different intensities over a variety of scales. Quantification of these variability and their dominant controls at multiple scales can only lead to a better understanding on the soil water dynamics in space and time and on the underlying processes causing the variability. In order to quantify spatio-temporal variability, soil water content (later converted to soil water storage, SWS) was measured down to 1.4 m (0.2 m depth interval) at 128 regularly spaced locations along a transect of 576 m over a five-year period from the Hummocky landscape of central Canada. The spatial pattern of SWS was very similar (large values of Spearman's rank correlation coefficient) over the entire study period and was almost a mirror image of the spatial pattern of the relative elevation. The similarity was stronger within a season (intra-season) than the same season from different years (inter-annual) and between seasons (inter-season). The variability at multiple scales was quantified using the wavelet transform. The strongest large scale (>72 m) variability contributed from the macro-topography and a moderate medium scale (18-72 m) variability contributed from the landform elements were persistent over the entire measurement period (time stability). The locations and the scales of the most persistent spatial patterns over time and depth were quantified using the wavelet coherency. The changes in the persistent patterns indicated the changes in the scales and locations of underlying hydrological processes, which can be used to identify change in sampling domain. The similarities/dissimilarities in the spatial pattern between the surface and sub-surface measurements at different scales and locations were used to infer the whole profile hydrological dynamics (depth persistence). The variability in SWS spatial patterns was controlled by different factors at different scales. Scale specific dominant controls were identified after separating the variance contribution of each scale towards the overall variance using the Hilbert-Huang transform. The large scale macro-topographical control and medium scale landform control were much stronger than very large scale soil textural control on SWS. The scale-specific relationship with controlling factors improved the prediction of SWS.