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Anomaly co-variations of large-scale hydrological fluxes across European climates

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Understanding the partitioning of precipitation water among different water fluxes and storage changes in the landscape, and the co-variations of these variables under various hydroclimatic conditions is essential for quantification and management of water resources and climate feedbacks. This study analyses the co-variation of temperature, precipitation, evapotranspiration, runoff and soil moisture anomalies based on data from two alternative sets of global observational and re-analysis products for 1378 catchments across three separate climate regions of Europe over the period 1980-2010. Co-variation details depend on both climatic zone and which of the alternative datasets is used for the analysis. However, consistently across all climate regions and both alternative datasets, the results show stronger correlation of soil moisture and runoff anomalies, than of the former and any of the other studied hydroclimatic variable anomalies. The latter findings of weak correlations include those of soil moisture with precipitation and evapotranspiration anomalies, even though the latter two hydroclimatic variables are commonly considered as most closely linked with soil moisture. The strong correlation between soil moisture and runoff also applies under extreme event occurrences for both wet and dry conditions, with the co-occurrences of extreme soil moisture and precipitation or evapotranspiration events being considerably less well linked. These results indicate soil moisture variations and associated closely linked groundwater table variations as key regulators of runoff variations, through changes in subsurface hydraulic gradients and associated groundwater flows into streams. In contrast, soil moisture and groundwater level variations do not co-vary as much and/or as quickly with precipitation and evapotranspiration anomalies because precipitation may primarily regulate evapotranspiration and, even under no precipitation conditions, there often still remains enough soil water available for the vegetation to keep transpiring and thus maintaining a relatively high evapotranspiration level. Overall, the results of this study emphasize the complex water flux and storage change connections by transport of both water-mass/volume and water-pressure though whole-catchment pathways, including their subsurface water parts, of various lengths. While the transport of water-mass/volume is slow and may take long time over long pathway distances, such as from many parts of the land surface (where precipitation and evapotranspiration act) to nearest stream (where runoff is observed), the groundwater table (i.e. groundwater pressure) and linked soil moisture (and soil water pressure) variations are faster and lead to quick and strong hydraulic gradient and associated runoff change responses along the entire stretches of short and long water pathways. These fast pressure response connections explain the strong correlations found consistently between soil moisture and runoff anomalies in this comprehensive multi-catchment and multi-climate study.