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Correlation between changes in water storage and deformation transients in karst systems: new insights from the European Alps

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We describe and discuss a hydrological transient deformation signal detected in geodetic measurements using a blind source separation algorithm. Space geodetic methods (GPS and SAR) have demonstrated their ability in measuring ground deformation associated with precipitation and groundwater redistribution at different spatial and temporal scales. We considered the results of a variational Bayesian Independent Component Analysis applied to the ground displacements time-series obtained from the analysis of continuous GPS stations operating in the Eastern Southern Alps and northern Dinarides. This analysis highlighted both annual common mode component signals and a time-variable, non-cyclic signal characterized by a spatially variable response in the horizontal components. This latter signal has larger amplitudes in three karst areas of the study region. The GPS stations respond to this signal by moving in opposite direction, reversing the sense of movement in time, implying a succession of extensional/compressional strains, with variable amplitudes through time, oriented normal to rock fractures in karst areas. Here we focus on the Val Belluna (i.e. Piave river basin) and the pedemountain front of the Venetian Southern Alps, and tested the hypothesis that the succession of horizontal extensions and contractions recorded by the GPS stations are caused by the variation of the water storage in the hydrological basin of this area. In a hydrological basin it is possible to define the storage variation as the difference between the total precipitation and the sum of real evapotranspiration and river discharge. In this work we used different hydrological models that are able, once calibrated on existing data, to estimate the actual evapotranspiration from potential evapotranspiration data. In addition, these models can describe the behavior of the basin also in the past, when no river-flows data were available. The only input data needed are precipitation and potential evapotranspiration and the model itself calculates the discharge, the storage and the actual evapotranspiration values. We found an excellent agreement between the temporal evolution of the water storage and the ten-year-long temporal evolution of the transient geodetic deformation signal. Then, this result provides new insights on the relation between water redistribution and ground displacements. We also found that the horizontal deformation can be explained by pressure changes associated with variable water levels within vertical fractures in the vadose zones of karst systems.