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Spatial and temporal variability of piezometric response at the small catchment scale

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In small mountainous and humid watersheds, characterized by complex topography and shallow soils, transient subsurface flow patterns often show a marked variability in space and time. Investigating such variability offers new insights for a better comprehension of the catchment hydrological behaviour.
In this study, we analyze the piezometric response of a small alpine watershed (Larch Creek Catchment, 0.033 km^2) in the Italian Dolomites. Water table variations recorded from late spring to early autumn 2009 by a net of 13 piezometric wells were used to assess: i) the main controls on the catchment piezometric response ii) the influence of topography on the spatial variability of subsurface flow patterns, ii) the temporal dynamics characterizing the subsurface flow activation.
Results show that a combined threshold of rainfall amount and antecedent wetness has to be exceeded to trigger the piezometric response. However, a precipitation amount greater than 20 mm (in 3 to 20 hours, according to the event properties), independently from the antecedent wetness conditions, leads to the activation of all piezometric wells. The magnitude of piezometric response (defined as the difference between piezometric peak and pre-event water table level) appear highly correlated with the event rainfall depth.
Correlation analysis between topographic features and properties of piezometric response for each well finds the local slope and the distance from stream to be the most significant topographic predictors of water table level, number of activations and response time (defined as the time lag between the storm centroid and the piezometric peak).
Cluster analysis of water table level allowed to identify a priori two watershed areas (a steep far-stream zone and a relatively flat near-stream zone) characterized by different groundwater dynamics. The different timing of piezometric response in the two zones leads to hysteretic relationships between streamflow and water table and between water table level in the near- and far-stream zone. The amplitude of the hysteretic loops is influenced by the storm properties and the antecedent wetness conditions. Higher correlation between streamflow and groundwater for the entire monitoring period are found in the near-stream zone, characterized by lower piezometric variability and groundwater dynamics more similar to stream runoff than the far-stream zone. The different hydrological behaviour observed in the two watershed areas is also confirmed by the application of TOPMODEL, that performs better (highest values of Nash-Sutcliff index and lowest values of Root Mean Square Error) when simulating the subsurface flow patterns in the near-stream zone than in the far-stream zone.

Key words: piezometric response, groundwater dynamics, near-stream zone, catchment topography.