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Modeling spatial and temporal hydrologic variability of karst vulnerability at a large Slovenian karst aquifer

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About 50% of the Slovene drinking water demand are covered by karst aquifers. Consequently, appropriate protection and sustainable management of these aquifers are essential. Due to the hydrologic complexity and variability of karst systems, predicting potential contaminations and aquifers' responses to changes in climate conditions, remains a challenge for karst research. In this study, the dynamics of potential solute contaminant transport in the Unica springs catchment, located in the southwest of Slovenia, are characterized and simulated with a semi-distributed karst model. The catchment encompasses autogenic and allogenic recharge across an area of about 820 km². The autogenic karst massive hosts one of Europe's largest confluences of subterranean river branches and is strongly karstified. To take into account the temporal and spatial characteristics of the catchment, the model is linked with a GIS-based approach to assess spatiotemporal karst vulnerability. The validation of the model is performed by discharge observations and tracer experiments. The resulting simulations enable us to identify hot spots and hot moments of high contamination risks. By simulating solute contaminant transport during extremely dry and extremely wet years, we show that contaminant transport slows down under dry conditions. This can be explained by fast flow pathways not being activated or hydraulically connected under low flow conditions, which results in a retention and dilution of the contaminant in the aquifer. Our new approach improves the understanding of potential contaminants' transport behavior in a large complex karst system and justifies the consideration of spatiotemporal hydrologic variability in solute transport forecasting. It proposes a good basis for a better evaluation, management and protection of water resources in karst areas.