EGU21-1533, updated on 28 Jan 2022
https://doi.org/10.5194/egusphere-egu21-1533
EGU General Assembly 2021

Effects of hydropeaking on groundwater mixing: from laboratory experiments to field scale observations

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Hydropeaking, an artificial flow regime consisting on strong and frequent river stage fluctuations, is known to have important effects on groundwater-surface water interaction. It influences the transient dynamics of water flow and also of solute and energy fluxes between aquifers and rivers. In this work, we focus on the effects of hydropeaking at multiple spatial and temporal scales. We start the investigation at the laboratory scale using quasi-two-dimensional flow-through experiments in which we can characterize flow and transport mechanisms, as well as the topology of the flow field, at high spatial and temporal resolution. We measure and model the spatial moments, the dilution index and the Okubo-Weiss parameter of a transient plume, and find a correlation between changes in flow topology and mixing enhancement. We then investigate a two-dimensional field scale cross section representative of the Adige aquifer in North-East Italy, where two rivers differently affected by hydropeaking influence groundwater flow, and we investigate the system considering hourly and mean daily fluctuations in the river stage. We characterize the transient groundwater dynamics for this and for other aquifers affected by hydropeaking using the Townley number, analyzing the potentiality of such systems for chaotic advection. Finally, at regional scale we use a three-dimensional transient model to show how the Adige aquifer is differently affected by hydropeaking depending on dry and wet years. Moreover, we apply the continuous wavelet transform to identify the main temporal scales of variability detected in the groundwater fluctuations and how they change with time. Our work therefore highlights the relevance of the effect of hydropeaking on groundwater flow and transport processes, and its impact on flow topology and mixing enhancement at multiple spatial and temporal scales.