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Estimating the timescale of the seawater retreat in coastal aquifers: Dimensional analysis and numerical investigations

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Submarine groundwater discharge (SGD) constitutes an important source of contaminants to the coastal ocean. Large fluxes of SGD are related to the retreat of the freshwater-saltwater interface, occurring during the period of the year, when the groundwater levels in the aquifer are high (usually in spring or summer). The estimation of the groundwater fluxes discharging to the coastal ocean as well as the timescale of the process are of crucial importance, since they are related to the actual chemical loading of the coastal waters during the swimming period. For the investigation of groundwater hydraulics in the coastal area, both analytical and numerical methods have been presented in the literature. The former are usually based on simplifying approximations which assume that (a) the freshwater and the saltwater are immiscible fluids (sharp interface approach) and (b) the pressure distribution in the freshwater area is hydrostatic and the saltwater is stationary (Gyben-Herzberg assumption). However, such solutions mainly concern steady state problems with simple geometrical and geological conditions, without accounting for the temporal component of each phenomenon. Numerical models which take into consideration the mixing between saltwater and fresh water, allow for more complete analysis of complicated problems, however, they require considerable computational effort.

In this study we present a simple finite differences model based on the sharp interface approach, which is used in order to investigate the dynamics of the SGD in periods when the freshwater-saltwater interface is in retreat and the rate of SGD is large. The reliability of the model is investigated by performing sensitivity analysis of the simulation results relatively to the spatial and temporal discretization. The purpose of our simulations is to derive simple relationships that allow estimation of (a) the timescale of seawater retreat phenomena and (b) the magnitude of the SGD-rates, as function of the geometrical and hydraulic characteristics of the aquifer, as well as the boundary conditions. Finally, we use dimensional analysis applied to the associated differential equations, in order to generalize our evaluation.