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The pseudo-coupled approximation of the variable-density flow model of seawater intrusion in coastal aquifers revisited

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The *pseudo-coupled* [PS-C] approximation of variable-density flow [VDF] is an intermediate-complexity model of seawater intrusion [SWI] in coastal aquifers that treats water flow and salt transport as *uncoupled inside the aquifer*, considering salt as a *hydrodynamically passive tracer*, but accounts for dispersion ignored by *hydraulic interface flow* models. PS-C models provide the salinity distribution, and hence insight needed to realistically gauge the risk of groundwater contamination. Considering the flow as unaffected by the solute –as *knowable from the hydraulics alone*– allows solving the transport equation separately with a *tracer* transport code, achieving very high efficiency relative to coupled VDF simulations. Heretofore however, the PS-C approximation has been found to hold under very restricted conditions.

Here, we present a SWI modelling approach that improves the accuracy of PS-C solutions. Key to that approach is defining the solution domain as the *through-flow* area bounded below by the (nominal) *interface*, which approximates the flow field's separation streamline and on which the salinity is set at one-half the sea-salinity (the interface is corrected for transverse dispersion, finite outflow area and reduced penetration length). Working in the *through-flow domain* circumvents the circulation cell of high-salinity groundwater forming near the coast. We compare the PS-C solutions to the coupled VDF solutions for Henry's problem –SWI in a confined coastal aquifer with constant freshwater inflow– for conditions characterised by the following parameter values: aspect ratio 0.005 $\leq \xi$ = (thickness d)/(length L) $\leq$ 0.5, *coupling parameter* 1 $\leq \alpha$ = (density contrast δ = 1/40)/(global head gradient $\Delta h_o/L$) $\leq$ 25, dispersivities ratio $r_\alpha = \alpha_T/\alpha_L$ = 0.1 and Peclet number 100 $\leq$ ***P*** = L/α_L $\leq$1500.

Using the coupled VDF solutions as benchmark, we show that the applicability range of *through-flow-domain* PS-C solutions is enlarged vis-à-vis that of *all-domain* PS-C solutions at least twentyfold, as indicated by the value of α. The enhanced accuracy of the *through-flow* PS-C model is attributed to approximating the 50%-salinity line well via the corrected interface, which enables starting the integration past the high-salinity circulation region near the sea-boundary and the aquifer base. In contrast, the *all-domain* PS-C model performs poorly, because it handles poorly that highly saline part of the domain, where the PS-C assumption holds only weakly; the consequence is the corruption of the *all-domain* PS-C solution in the remaining SWI area, and gross underestimation of SWI.