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A simulation-optimization model for effective water resources management in the coastal zone

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Coastal areas are the most densely-populated areas in the world. Consequently water demand is high, posing great pressure on fresh water resources. Climatic change and its direct impacts on meteorological variables (e.g. precipitation) and indirect impact on sea level rise, as well as anthropogenic pressures (e.g. groundwater abstraction), are strong drivers causing groundwater salinisation and subsequently affecting coastal wetlands salinity with adverse effects on the corresponding ecosystems. Coastal zones are a difficult hydrologic environment to represent with a mathematical model due to the large number of contributing hydrologic processes and variable-density flow conditions. Simulation of sea level rise and tidal effects on aquifer salinisation and accurate prediction of interactions between coastal waters, groundwater and neighbouring wetlands requires the use of integrated surface water-groundwater mathematical models. In the past few decades several computer codes have been developed to simulate coupled surface and groundwater flow. However, most integrated surface water-groundwater models are based on the assumption of constant fluid density and therefore their applicability to coastal regions is questionable. Thus, most of the existing codes are not well-suited to represent surface water-groundwater interactions in coastal areas.

To this end, the 3D integrated surface water-groundwater model IRENE (Spanoudaki et al., 2009; Spanoudaki, 2010) has been modified in order to simulate surface water-groundwater flow and salinity interactions in the coastal zone. IRENE, in its original form, couples the 3D shallow water equations to the equations describing 3D saturated groundwater flow of constant density. A semi-implicit finite difference scheme is used to solve the surface water flow equations, while a fully implicit finite difference scheme is used for the groundwater equations. Pollution interactions are simulated by coupling the advection-diffusion equation describing the fate and transport of contaminants introduced in a 3D turbulent flow field to the partial differential equation describing the fate and transport of contaminants in 3D transient groundwater flow systems. The model has been further developed to include the effects of density variations on surface water and groundwater flow, while the already built-in solute transport capabilities are used to simulate salinity interactions. The refined model is based on the finite volume method using a cell-centred structured grid, providing thus flexibility and accuracy in simulating irregular boundary geometries.

For addressing water resources management problems, simulation models are usually externally coupled with optimisation-based management models. However this usually requires a very large number of iterations between the optimisation and simulation models in order to obtain the optimal management solution. As an alternative approach, for improved computational efficiency, an Artificial Neural Network (ANN) is trained as an approximate simulator of IRENE. The trained ANN is then linked to a Genetic Algorithm (GA) based optimisation model for managing salinisation problems in the coastal zone. The linked simulation-optimisation model is applied to a hypothetical study area for performance evaluation.

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