The interaction of basin-scale gravity-driven groundwater flow and free thermal convection

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ABSTRACT
Two-dimensional numerical model calculations have been carried out to investigate the distortion of basin-scale groundwater flow system driven by water table differences due to heterogeneous temperature distributions. A Tóthian homogeneous unit basin (1962) with constant slope of the water table was used for the simulations. Equations of the conservation of mass, heat transport and Darcy's law with temperature-dependent water density were solved to handle the problem of interaction of different driving forces, free thermal convection and water table gradients.
Temperature differences between the bottom and the surface of the basin (ΔT) were systematically varied to reveal the influence of thermal convection on the observed parameters such as the Darcy velocity components, hydraulic head, temperature, and heat flux time series. For the chosen model parameters, the groundwater system converged to a stationary solution for ΔT<60 °C and if the heat was advected toward the discharge area dominantly by 'gravitational flow'. In the case of ΔT=60 °C, a stationary equilibrium formed in the recharge area where the hot upwelling water from the lower boundary was balanced by the cold downwelling water from the surface. In this model, the thermal Rayleigh number was approximately 750 indicating the effect of free convection. Time-dependent solutions were found for those scenarios where ΔT>60 °C. Hot upwellings formed from the base and were swept toward the discharge area by gravitational flow. However, a pulsating long-lived hot plume also evolved beneath the recharge area as a result of a dynamic equilibrium between the hot upwelling and cold downwelling water. Dominant frequencies of the time series of the monitoring parameters reflect the dynamics of the system that reflects plume formation, migration by gravitational flow and pulsation. Discontinuous increases in the quasi-stationary solution of the observed parameters (Darcy's velocity, hydraulic head, temperature and heat flux) define the conditions where the role of the free thermal convection becomes commensurable with the groundwater flow controlled by water level differences. The theoretical simulations represent the consequences of the interaction of the different driving forces in space and time for the simulated domain.
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References
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