Geophysical Research Abstracts
Vol. 20, EGU2018-455, 2018
EGU General Assembly 2018

Numerical investigation of the combined effect of basin-scale forced and free thermal convection

Márk Szijártó (1), Attila Galsa (1), Ádám Tóth (2,3), Judit Mádl-Szőnyi (2,3)

(1) Eötvös Loránd University, Department of Geophysics and Space Science, Budapest, Hungary (szijartomark@gmail.com), (2) Eötvös Loránd University, Department of Physical and Applied Geology, Budapest, Hungary, (3) József and Erzsébet Tóth Endowed Hydrogeology Chair, Budapest, Hungary

Based on earlier conceptions water table configuration was examined as the unique driving force of regional groundwater motion. Since that time it has been perceived, that density change by heat transfer can be a further driving force for groundwater flow, too. It was certified analytically the existence of thermal convection in a two-dimensional, horizontally infinite porous medium, when the Rayleigh number exceeded the critical value, $Ra>Ra_{cr}=4\pi^2$. Although *Domenico* and *Palciauskas* [1973] investigated the relationship between the topography-driven groundwater flow and heat transfer, they focused only on the phenomenon of forced convection, while the effect of buoyancy was neglected. Recognizing the importance of free thermal convection, *Cserepes* and *Lenkey* [2004] studied the flow pattern as a function of the slope of the topography ($\gamma <0.1^{\circ}$) and the Rayleigh number ($Ra<160$).

In this study, the combined effect of the forced and free thermal convection was investigated numerically on the groundwater flow pattern and temperature field. A simple two-dimensional homogeneous, isotropic unit basin [*Tóth*, 1962] with constant slope ($\gamma=1^{\circ}$) was applied to focus on the physics of the phenomenon. Temperature difference between the bottom and the surface of the basin was increased from ΔT=0 to 150 °C, while the variation of the Darcy's velocity, the temperature and the hydraulic head was computed. This range of the temperature difference covers the values of *Ra*=0–3500 including transitions from stationary, forced convection dominated state (ΔT <60 °C, $Ra<960$) to time-dependent, quasi-stationary or weakly chaotic, free convection dominated state (ΔT >60 °C, $Ra>960$). In order to understand the quasi-periodic behavior of the flow, time series analysis was carried out on the calculated parameters. Additionally, it was established that the increase in ΔT enhances the relative area of the basin up to 40% where the thermal convection influences the head inducing over- and underpressure. The locations where the hydraulic head is significantly affected by the free thermal convection are (1) within and around the plume beneath the recharge area, (2) in the deeper parts of the midline zone and (3) the majority of the discharge area. By increasing the temperature difference, the position of head maximum jumps from the highest point of the water table to the bottom of the basin, where it separates the local downflow, like a moving divergent stagnation point. This simulation draws attention to the potential and the importance of the combined effect of forced and free thermal convection in basin-scale groundwater flow pattern and temperature distribution (e.g. geothermal resources management and thermal water research).

This project was supported by the János Bolyai Research Scholarship of the Hungarian Academy of Sciences.

References:

Cserepes, L. and Lenkey, L. (2004), Forms of hydrothermal and hydraulic flow in a homogeneous unconfined aquifer, Geophys. J. Int., 158(2), 785-797

Domenico, P.A. and Palciauskas, V.V. (1973), Theoretical analysis of forced convective heat transfer in regional ground-water flow, GSA Bulletin, 84(12), 3803-3814

Tóth, J. (1962), A theory of groundwater motion in small drainage basins in central Alberta, Canada, J. Geophys. Res., 67(22), 1375-4387