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A DEM-based residual kriging model for estimating groundwater levels within a large-scale domain: a study for the Fuyang River Basin

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Abstract It is a basis of the effective groundwater resources management to understand the movements and changes of groundwater, wherein the information about spatial distribution of groundwater levels is indispensable. Geostatistical methods like kriging have been widely used to estimate groundwater levels based on observation wells. The errors are inevitably introduced through the interpolation process; hence, how to increase the accuracy, which is based on limited well data, has become an urgent issue for estimating groundwater levels, especially for a large area. This study developed an integrated DEM-based residual kriging model for estimating groundwater levels within a large-scale domain. The model can yield more physically plausible estimates of groundwater levels in a large-scale domain than those currently in use by effectively utilizing well data and considering the influences of terrain morphology on the groundwater flow. The model was then applied to the Fuyang River Basin, a 5,000 km^2 investigating area, in the North China for estimating the regional groundwater levels and flow. The Kolmogorov–Smirnov test was employed to prove that the DEM information could markedly facilitate the residuals to approach a normal distribution, which insures satisfied estimate accuracy. For demonstrating the advantages of the proposed DEM-based trend surface, three types of trend surface using both simple and quadratic equations were developed to estimate groundwater levels. Based on the verification points, the mean error, the mean absolute error, and the square root of the quadratic multiply error, for each trend-surface equation were compared. The DEM-based trend surface equations were discovered with the highest accuracy. The results indicated that quadratic equation could more effectively present the trend surface than simple one with a higher correlation coefficient. However, for a large-scale estimation domain with limited well data, the simple equation for DEM-based trend surface showed more feasible with better accuracy than the quadratic one. Further research on improving trend-surface simulation to more effectively reflect system complexities would be desired.

Keywords Digital elevation model (DEM) · Residual kriging · Estimation · Groundwater levels · Large-scale domains · The Fuyang River Basin

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Introduction

World water demand doubles every 20 years due to the rapidly expanding society, accelerating economy, and growing population (USAID 2003). To meet the increasing water demand, groundwater is withdrawn as an important supply source and the extraction amount is kept elevating. The continuous quest for water is evident as well drillers chase the water table downward (Brown 2001). Gradually, over extraction of groundwater becomes a growing wordwide problem, which leads to adverse environmental effects, such as groundwater-level decline, depression-cone