Unraveling elastic and inelastic storage of aquifer systems by integrating fast independent component analysis and a variable pre-consolidation head decomposition method

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Abstract

Groundwater overexploitation is the main reason for land subsidence. A numerical model is used to simulate and predict land subsidence. The parameters used to estimate land subsidence include the elastic skeletal storage coefficient (S_{ke}), inelastic skeletal storage coefficient (S_{kv}), and the related specific values (S_{ske} and S_{skv}). This paper used a novel approach that integrates fast independent component analysis (Fast-ICA) with variable pre-consolidation head decomposition to separate the elastic (S_{ske}) and inelastic (S_{skv}) skeletal specific storage at various depths and time from piezometric and extensometer recordings. The proposed method is applied to the severely subsiding areas in the North China Plain (Tianzhu, Pinggezhuang, and Cangzhou stations). The elastic and inelastic characteristics of the aquifer system are measured at various depths. The results show that S_{ske} and S_{skv} decline with depth. The S_{ske}/S_{skv} ratio decreases with increasing sedimentary particle size. Additionally, when the quantity of soil compaction or land subsidence increase, S_{kv} decreases but S_{ke} remains constant over time. The relations between the storage parameters and depth, lithology, and time are explored based on the determined storage values. The values of S_{ske} and S_{skv} at different aquifer systems generally decrease with depth. At Tianzhu station, S_{ske} decreased from 2.9×10^{-5} m^{-1} to 3.5×10^{-6} m^{-1} with the depth increasing from 48.5 to 64.5 m to 148.49 – 218.89 m. As to the inelastic component, S_{skv} decreased from 1.5×10^{-4} m^{-1} to 2.2×10^{-5} m^{-1} with the depth increasing from 82.3 to 102 m to 148.49 – 218.89 m.

Keywords: Land subsidence, Elastic skeletal specific storage, Independent component analysis, Variable pre-consolidation head

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Research papers

Unraveling elastic and inelastic storage of aquifer systems by integrating fast independent component analysis and a variable preconsolidation head decomposition method

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ABSTRACT

Land subsidence is a geological process mainly caused by groundwater overdraft. Numerical modeling of land subsidence is the main method used for its simulation and prediction. The elastic skeletal storage coefficient (S_{ke}), inelastic skeletal storage coefficient (S_{kv}), and the related specific values (S_{ske} and S_{skv}) are fundamental parameters to quantify land subsidence. In this paper, a novel approach integrating fast independent component analysis (Fast-ICA) with variable preconsolidation head decomposition method is proposed to disentangle S_{ske} and S_{skv} at various depth and over time from piezometric and extensometer records. The proposed method is applied to areas affected by severe land subsidence in the North China Plain (Tianzhu, Pinggezhuang and Cangzhou stations). The elastic and inelastic parameters of the aquifer systems are quantified at different depths. It is found that S_{ske} and S_{skv} decrease with depth. The finer the sediment grain size is, the smaller of the ratio S_{ske}/S_{skv}. Moreover, S_{ke} remains almost unchanged over time, while S_{kv} decreases as compaction and land subsidence increase.