Long-Term Deformation Monitoring and Analysis of Shale Gas Exploitation: A Case Study from Weiyuan West, Sichuan, China

Shihao Dai, Yingwen Zhao, Caijun Xu, Gang Chen and Qi Wang (China, PR)

Key words: Deformation measurement; Remote sensing; SBAS-InSAR; T-PCA; Deformation in shale gas extraction; microseism

SUMMARY

With the implementation of China's carbon peaking and carbon neutrality goals, the demand for clean energy has continued to grow. Shale gas, characterized by abundant reserves and relatively low carbon emissions, has been extensively developed in China in recent years. However, long-term shale gas extraction has led to significant surface deformation and numerous microseismic events, including some with magnitudes greater than 5. Previous studies have suggested that fluid injection during hydraulic fracturing may exert long-term effects on the subsurface stress field, which could potentially be detected through the temporal evolution of surface deformation in the production area. In practice, however, the surface deformation in shale gas fields is highly complex, resulting from multiple processes including pore pressure increase induced by hydraulic fracturing, tectonic deformation, and aseismic slip. Therefore, accurately obtaining long-term deformation time series, investigating their spatiotemporal patterns, and exploring their relationship with microseismic activity are crucial for ensuring the safe development of shale gas fields and for understanding the mechanisms of anthropogenic seismicity. In this study, we applied a combination of the Small Baseline Subset Interferometric Synthetic Aperture Radar (SBAS-InSAR) method and the Temporal Principal Component Analysis (T-PCA) technique to extract the surface deformation in the Weiyuan West shale gas field. We further analyzed the spatiotemporal correlation between the extracted deformation, shale gas production platforms, and the microseismic catalog. The results indicate that: (1) the joint SBAS-InSAR and T-PCA approach effectively captures the temporal evolution, spatial distribution, and the surface deformation induced by shale gas extraction in the Weiyuan West area; (2) both microseismic events ($M < 3$) and moderate earthquakes ($3 < M < 5$) are primarily concentrated in regions exhibiting significant deformation; and (3) the temporal variations in deformation reflect the development progress and intensity of shale gas extraction, with most seismic events occurring during periods of intensive production activity. This study utilized geodetic techniques to accurately monitor the impact of

shale gas extraction on the Earth's surface and found a strong spatiotemporal correlation between microseismic events and shale gas production, providing important insights for ensuring the safe development of shale gas and for investigating the mechanisms of industrially induced earthquakes.