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Production-induced three-dimensional surface displacement over oil/gas fields measured by InSAR and its induced environmental impacts

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Oil and gas production can cause a drop in pore pressure within the reservoir, increasing effective stress and resulting in reservoir compaction. Subsurface reservoir compaction propagates to the Earth's surface, manifesting as land subsidence, which can damage oil/gas production facilities and surface infrastructure. When oil and gas fields are situated in low-lying delta regions, land subsidence exacerbates the impact of flooding and inundation. A three-dimensional (3D) displacement field is expected over an oil/gas-producing field due to oil reservoirs' typically significant burial depth relative to their horizontal extent. In this study, we proposed a novel method to retrieve the complete 3D displacement field over producing oil/gas fields. By integrating multi-geometry InSAR line-of-sight (LOS) observations, we derived the vertical and east-west displacement components, while the north-south component was estimated based on an assumed physical relationship between horizontal and vertical displacements. We applied this method to the oil fields in Liaohe River Delta in Northeastern China and the Sebei gas fields in Northwestern China. The derived 3D displacement field reveals a circular subsidence bowl with a maximum subsidence rate of ~20 cm/year at the center, accompanied by a centripetal pattern of horizontal displacements with maximum rates of ~5 cm/year directed toward the subsidence center. The retrieved 3D displacements align well with predictions from geomechanical modeling, which assumes a disk-shaped reservoir undergoing a uniform reduction in pore fluid pressure. Finally, we highlight infrastructure damage caused by oil production-induced land subsidence and its impact on flood inundation in the low-lying Liaohe River Delta.