Identifying attributes of CO_2 leakage zones in shallow aquifers using a parametric level set method

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Abstract

Leakage through abandoned wells and geologic faults poses the greatest risk to CO_2 storage permanence. For shallow aquifers, secondary CO_2 plumes emanating from the leak zones may go undetected for a sustained period of time and has the greatest potential to cause large-scale and long-term environmental impacts. Identification of the attributes of leak zones, including their shape, location, and strength, is required for environmental risk assessment. This study applies a parametric level set (PaLS) method to characterize leak zones. Level set methods are appealing for tracking topological changes and recovering unknown shapes of objects. However, level set evolution using the conventional level set methods is computationally challenging. In PaLS, the level set function is approximated by using a weighted sum of basis functions and the level set evolution problem is replaced by an optimization problem. The efficacy of PaLS is demonstrated by reconstructing attributes of a CO_2 leak zone in a carbonate aquifer. Our results show that PaLS is a robust source identification method that can recover the approximate leak zone locations in the presence of measurement errors, model parameter uncertainty, and inaccurate guesses of source flux strengths. Accurate delineation of source geometry is achievable when a relatively dense observation network is used. The PaLS-based, source recovery framework introduced in this work is generic and can be adapted for any reactive transport model by simply switching the pre- and post-processing routines.