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# An advanced approach for upscaling hydrogen migration in diverse saline aquifers

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Leveraging various energy storage techniques spanning daily, weekly, and seasonal cycles offers a pathway to lower carbon dioxide emissions per energy unit. Employing renewable energy for hydrogen production, storage, and recycling emerges as a highly viable tactic to manage seasonal energy fluctuations. Deep saline aquifers provide a practical solution for extensive hydrogen storage, specifically designed to fulfill long-term storage needs. This study introduces a percolation theory-based upscaling technique to lower computational expenses when simulating H2 movement across diverse saline aquifers with varying correlation lengths. Two geological models, each with different correlation lengths, illustrate the efficacy of this method. In the model featuring a 1.2-meter correlation length, the percolation-based upscaling results in H2 saturation errors of 8.76% in the primary area and 3.7% in the sink area, reducing runtime by almost sevenfold. Similarly, in the model with a 4.0-meter correlation length, final H2 saturation errors of 10.7% in the main area and 1.27% in the sink area are achieved, decreasing runtime by nearly fivefold. To enhance the credibility of the proposed upscaling technique, parameters derived from the Brooks-Corey and van Genuchten models are fine-tuned to match experimentally obtained properties of H2-water multiphase flow. The resulting broader-scale model accurately reproduces primary permeability and H2 migration patterns, maintaining errors below 5%. Crucially, key mechanisms governing H2 movement during subterranean hydrogen storage in saline aquifers are retained in the upscaled models, enabling efficient predictions of H2 saturation beneath caprock. This research deepens our insight into the intricate H2 migration at a smaller scale within complex geological systems and sheds light on incorporating the characteristics of small-scale capillary barriers during upscaling.

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## References

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