The cross-scale science of CO_2 capture and storage: from pore scale to regional scale

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Abstract

We describe state-of-the-art science and technology related to modeling of CO_2 capture and storage (CCS) at four different process scales: pore, reservoir, site, and region scale. We present novel research at each scale to demonstrate why each scale is important for a comprehensive understanding of CCS. Further, we illustrate research linking adjacent process scales, such that critical information is passed from one process scale to the next adjacent scale. We demonstrate this cross-scale approach using real world CO_2 capture and storage data, including a scenario managing CO_2 emissions from a large U.S. electric utility. At the pore scale, we present a new method for incorporating pore-scale surface tension effects into a relative permeability model of CO_2-brine multiphase flow at the reservoir scale. We benchmark a reduced complexity model for site-scale analysis against a rigorous physics-based reservoir simulator, and include new system level considerations including local site-scale pipeline routing analysis (i.e., reservoir to site scale). We also include costs associated with brine production and treatment at the site scale, a significant issue often overlooked in CCS studies. All models that comprise our total system include parameter uncertainty which leads to results that have ranges of probability. Results suggest that research at one scale is able to inform models at adjacent process scales, and that these scale connections can inform policy makers and utility managers of overall system behavior including the impacts of uncertainty.