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Monitoring Surface CO₂ Fluxes During Two Shallow Subsurface CO₂ Releases

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The ZERT project's shallow release facility on the Montana State University campus provides the opportunity to test field methods to detect and quantify potential CO₂ leakage from geologic storage sites. CO₂ release experiments were conducted from a ~100-m long horizontal well installed at ~2.5 m depth, sub-water table, within a sandy cobble. The well was separated into six zones by inflatable packers, from which 0.1 t CO₂ d⁻¹ was released for ten days starting 07/09/2007 (Release 1), and 0.3 t CO₂ d⁻¹ was released for seven days starting 08/05/2007 (Release 2). We measured soil CO₂ fluxes using the chamber method on grids repeatedly on a daily basis and net CO₂ fluxes continuously using the eddy covariance technique. Based on chamber measurements near the well, CO₂ breakthrough at the surface occurred on day two of Release 1. The spatial distribution and magnitude of leakage fluxes reached quasi-steady state by day six. Fluxes returned to near those measured at background locations two days following the end of Release 2. Spatial patterns in chamber CO₂ fluxes were strongly related to well design. Estimates of total, background (soil respiration), and leakage CO₂ discharges (t d⁻¹) based on chamber measurements showed that during Release 1, background CO₂ discharge was relatively high but declined at nearly the same rate as leakage discharge increased, leading to little change in total discharge. Conversely, during Release 2, background soil respiration remained low relative to leakage discharge.

Because the comparatively large spatial footprint of the eddy covariance measurements averages over both background and well locations, CO₂ leakage signals were difficult to detect by eddy covariance during Release 1, while during Release 2, signals were clearly detectable. Our results emphasize the influence of background CO₂ flux variations on the ability to detect leakage signals.