

Numerical simulation of alteration patterns induced by sequestration of CO₂ in a carbonate-hosted saline aquifer

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We run reactive transport simulations to understand the transient chemical processes that occur in a carbonate-dominated aquifer during and after the injection of CO₂. The model, its design and its initial and bounding physico-chemical conditions, are patterned after the Upper Muschelkalk-Gipskeuper aquifer-seal pair in the Molasse Basin in Northern Switzerland. Chemical processes are controlled by the dynamics of the CO₂ plume. Supercritical CO₂ is more buoyant than the brine. Consequently, the CO₂ plume tends to rise and spread laterally when it encounters the overlying Gipskeuper seal. Over time CO_{2,sc} dissolves into the brine, causing the density of the brine to increase. The denser brine tends to sink, initiating density driven convection. Depending on the permeability of the aquifer, sinking of the CO₂-enriched brine may occur in a complex finger-like pattern. The dissolution of CO₂ into the brine entails a lowering of the *pH* and hence the dissolution of the primary carbonate mineralogy. Because the brine remains buffered at local equilibrium with the carbonates, the dynamics of the CO₂ plume and the CO₂-enriched brine is reflected by the mineral alteration pattern. Although the drop in *pH* is associated with carbonate dissolution, the *pH* recovers in certain regions of the aquifer faster than in others, thus leading to a complex pattern of carbonate dissolution and reprecipitation. This evolving pattern of carbonate dissolution/precipitation implies that chemical constituents that are initially incorporated in or that coexist with primary carbonate minerals may be released into the fluid, then later removed from the fluid by reprecipitation when conditions have changed. Our simulations allow us to assess the release of solid constituents from the primary mineralogy into the brine as CO₂ injection proceeds.

The increase in reservoir pressure during injection, the dynamics of the CO₂ plume and the perturbation of chemical conditions in the reservoir will initiate mass transfer across the aquifer-seal interface and initiate chemical reactions on either side of the interface. We explore the extent of species mobilization and transfer across the reservoir/seal interface, identify the type of reactions that occur as well as their implications for the tightness of the caprock.

Sensitivity to deliberate seeding of marine clouds – Observations and modeling

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Sea salt seeding of marine clouds to increase their albedo is a proposed technique to counteract or slow global warming [1]. In this study, we first investigate the susceptibility of marine clouds to sea salt injections, using observational data of cloud droplet number concentration (CDNC), cloud optical depth, and liquid cloud fraction from the MODIS (Moderate Resolution Imaging Spectroradiometer) instruments on board the Aqua and Terra satellites. We then compare the derived susceptibility function to a corresponding estimate from the Norwegian Earth System Model (NorESM). Results compare well between simulations and observations, showing that stratocumulus regions off the west coast of the major continents along with large regions in the Pacific and the Indian oceans are sensitive.

We then carry out sensitivity experiments with a uniform increase of 10⁻⁹ kg m⁻² s⁻¹ of 0.13 μm radius sea salt over ocean, in alignment with earlier studies [2]. The increased sea salt concentrations and the resulting change in marine cloud properties lead to a globally averaged forcing of -5.9 Wm⁻² at the top of the atmosphere, more than cancelling a doubling of CO₂. The forcing is large in areas found to be sensitive by using the susceptibility function, confirming its usefulness as an indicator of where to inject sea salt. When the same sea salt mass is injected in the form of much smaller sea salt particles of 0.022 μm radius, a quite different result is found. These particles are too small to activate as CCN, but they provide a large surface area for sulphuric acid gas to condense on, thereby greatly suppressing the formation of sulphate particles. Therefore the overall CCN concentration is reduced, and the globally averaged forcing is positive.

[1] Salter (2008): *Phil. Trans. R. Soc. A*, **366**, 3989-4006.

[2] Latham (2008): *Phil. Trans. R. Soc. A*, **366**, 3969-3987.