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Time-lapse CSEM monitoring of the Ketzin (Germany) CO_2 injection using 2xMAM configuration

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Abstract

This paper deals with the electrical resistivity monitoring of the Ketzin CO_2 injection pilot (CO2ReMoVe EC project) through time-lapse CSEM measurements. There, 3 boreholes about 800 m deep have been especially designed for current injection at reservoir (sandstone) depth. CO_2 is directly injected in a saline (~240 g/l) aquifer. Prior modelling results indicated that the increase of electrical resistivity generated by the CO_2 plume (gaseous and liquid CO_2 phases) supposed to be highly resisitive, would generate measurable changes in the EM fields on the surface, when injecting current directly inside the reservoir. In order to highlight and follow these expected resistivity changes, 3 CSEM surveys were performed in August 2008 (baseline prior to injection), June 2009 and August 2010. Each time, 13 EM stations have been recorded during current injection of a square wave at 3 frequencies (0.125 Hz, 0.5 Hz and 4 Hz) in two configurations ("double mise à la masse" (2xMAM) and "mise à la masse – surface" (MAM-Surface)). This paper only presents results of the 2xMAM configuration at 0.5 Hz.
In spite of a very noisy area (gas pipes, high voltage power lines), we measured signal amplitude 10 times higher than noise amplitude. We show that EM fields vectors (both inphase and quadrature components) measured on the surface are very similar to the forward modelling EM responses computed with COMSOL Multiphysics®. Models also show that electric field spatial distribution is strongly affected by a thin and resistive layer (35 m - 200 Ωm) of anhydrite above the reservoir, making E field diverging from the boreholes whereas a dipolar pattern was expected for the dipole current injection used here. Moreover, while June 2009 survey highlighted the expected strong increase of electric field (increase of resistivity), August 2010 survey showed electric field amplitudes similar to the 2008 baseline survey, revealing therefore major changes of the reservoir properties. Finally, the directional sensitivity of the 2xMAM array is tested through modelling residuals computed for five CO_2 plume spatial distributions. Results show that a north-eastward migration of the CO_2 plume is expected to fit field data.

Keywords: CSEM; CO_2; Time-lapse monitoring; Mise à la masse; EM modelling; Ketzin

1. Introduction

Several teams [1; 2; 4; 6] have proposed to monitor CO_2 injection through the time-lapse variation of electrical resistivity at depth. This approach is especially appropriate in the case of a CO_2 injection in a saline reservoir where the CO_2 plume is expected to strongly modify the current paths due to an increase of electrical resistivity (for