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Results from twelve years of continuous monitoring of the soil CO₂ flux at the Ketzin CO₂ storage pilot site, Germany

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Abstract

The complete cycle of specific processes related to the geological storage of CO₂ is investigated in detail at Ketzin since 2004. The scientific monitoring program targets different depths of the involved area and addresses the safety and reliability of the storage. The surface monitoring comprises long-term soil CO₂ flux measurements and soil gas analyses. Annual mean values of soil CO₂ fluxes ranged from 2.4 to 3.4 μmol m⁻² s⁻¹ before the injection started (2005-2008) and from 2.3 to 3.5 μmol m⁻² s⁻¹ during and after CO₂ injection (2009-2016) and thus do not indicate an upward migration of the injected CO₂.

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Keywords: Ketzin pilot site; monitoring soil CO₂ flux; soil gas measurements

1. Introduction and motivation

Under the coordination of the GFZ German Research Centre for Geosciences the first European onshore CO₂ storage project was initiated in 2004 at Ketzin, approximately 25 km west of Berlin, Germany. About 67 kt of CO₂ (purity > 99.9%) were injected there into a saline aquifer from June 2008 until August 2013. All project stages were accompanied by a comprehensive monitoring and modelling program, focusing on the investigation of the processes involved and to assure leakage-free CO₂ injection and geological storage. Hence, methods from different geoscientific disciplines were applied, targeting the reservoir itself, the cap rock, the above-zone and the surface [1,2]. Here we report on the results of the long-term surface monitoring with continuous soil CO₂ flux measurements

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and complementary measurements of the soil gas composition and $\delta^{13}\text{C}_{\text{CO}_2}$ isotopic ratios at selected locations. A profound and extensive database of measurements performed before injection started serves to interpret data during and after CO_2 injection [3]. As the CO_2 flux measurements reflect the specific site conditions, which can vary locally and over time, trends must be interpreted carefully.

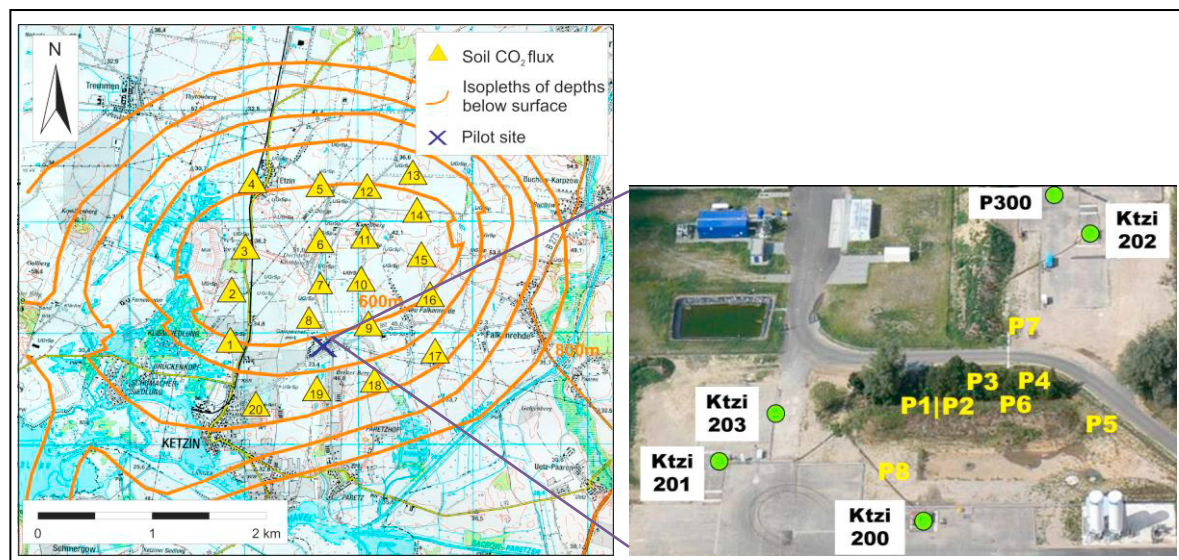


Fig. 1: Map of the Ketzin pilot site with 20 long-term surface sampling locations (triangles) and eight permanent locations at the injection site (blue cross and yellow squares on the photograph). Additionally, all five wells are depicted, with Ktzi 201 being the former injection well.

2. The Ketzin pilot site, the monitoring concept and methods

After an exploration phase in 2004 and drilling of the first wells in 2007, CO_2 was injected between 2008 and 2013 into Upper Triassic sandstones at a depth of 630 to 650 m. This reservoir is overlain by more than 165 m of shaley cap rocks. The site itself is located at the southern flank of the Roskow-Ketzin double-anticlinal structure [4,5,6] and the stored CO_2 mainly migrated in northern to western direction [2].

Monitoring at the surface started in 2005 with soil CO_2 flux measurements using a LI-8100 automated soil CO_2 flux system (LI-COR Biosciences) and a 10-cm survey accumulation chamber. The CO_2 concentration in the discharging soil air is measured with an integrated infrared gas analyzer. Twenty measuring locations were arranged in a 2.5 km x 2.5 km fixed sampling grid that covers (i) the potential area of subsurface CO_2 distribution and (ii) unaffected regions for comparison (Figure 1). The alignment of the sampling grid also considered geological and artificial structures e.g. faults, troughs [5,6] and wells. In order to obtain information on seasonal trends, measurements were performed once a month and since 2012 twice a month.

To refine the monitoring network grid, eight automated permanent 20-cm accumulation chambers (LI-COR) were additionally installed on site in 2011 in the direct vicinity of the injection and observation wells. Using this system, the CO_2 soil flux was measured on an hourly basis around the clock. Due to the automatic operation of the system without daily maintenance, technical problems (failure of sensors or clogging of the chamber by e.g. animals or leaves) have caused gaps in the data series. Simultaneously the soil temperature was recorded at all 28 stations with a thermocouple (Omega Engineering GmbH) and the weather conditions with a MWS 9-5 station (Reinhardt System- und Messelectronic GmbH).

Detailed soil gas analyses can give information about the origin of the CO_2 . As natural soil CO_2 is produced via consumption of O_2 during biogenic reactions and/or methane oxidation, the ratio of both gases is used for evaluation of the CO_2 origin. Moreover, it is assumed that the addition of CO_2 from leakage results in a physical dilution of the

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