Soil CO2 flux monitoring data from the Ketzin CO2 storage pilot site in the years 2005 to 2016

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Martin Zimmer[1], Peter Pilz[1], Alexandra Szizybalski[1], Merlin Nepomuk Ganzer[1]

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3. Data Description

Under the coordination of the German Research Centre for Geosciences GFZ 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 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 save geological storage. Hence, methods from different geoscientific disciplines were applied, targeting the reservoir itself, the cap rock, the above-zone and the surface (Martens et al. 2015, Wipki et al. 2016). Here we report on the results of the long-term surface monitoring with continuous soil CO2 flux measurements. A profound and extensive database of measurements performed before injection started serves to interpret data during and after CO2 injection (Zimmer et al. 2011). As the CO2 flux measurements reflect the specific site conditions, which can vary locally and over time, trends must be interpreted carefully. After an exploration phase in 2004 and drilling of the first wells in 2007, CO2 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 (Martens et al. 2014, Förster et al. 2006, Förster et al. 2009) and the stored CO2 mainly migrated in northern to western direction (Wipki et al. 2016).

Additionally, soil profiles of 70 cm depth were studied for their structure and carbon and nitrogen concentrations. The results helped to explain the spatial variations of the soil CO2 fluxes at the different locations (Zimmer et al. 2011). However, as most of the sampling positions are located next to agricultural roads and fields, an influence of used fertilizers and arable farming on the soil structure, chemical composition and the soil biology cannot be ruled out.

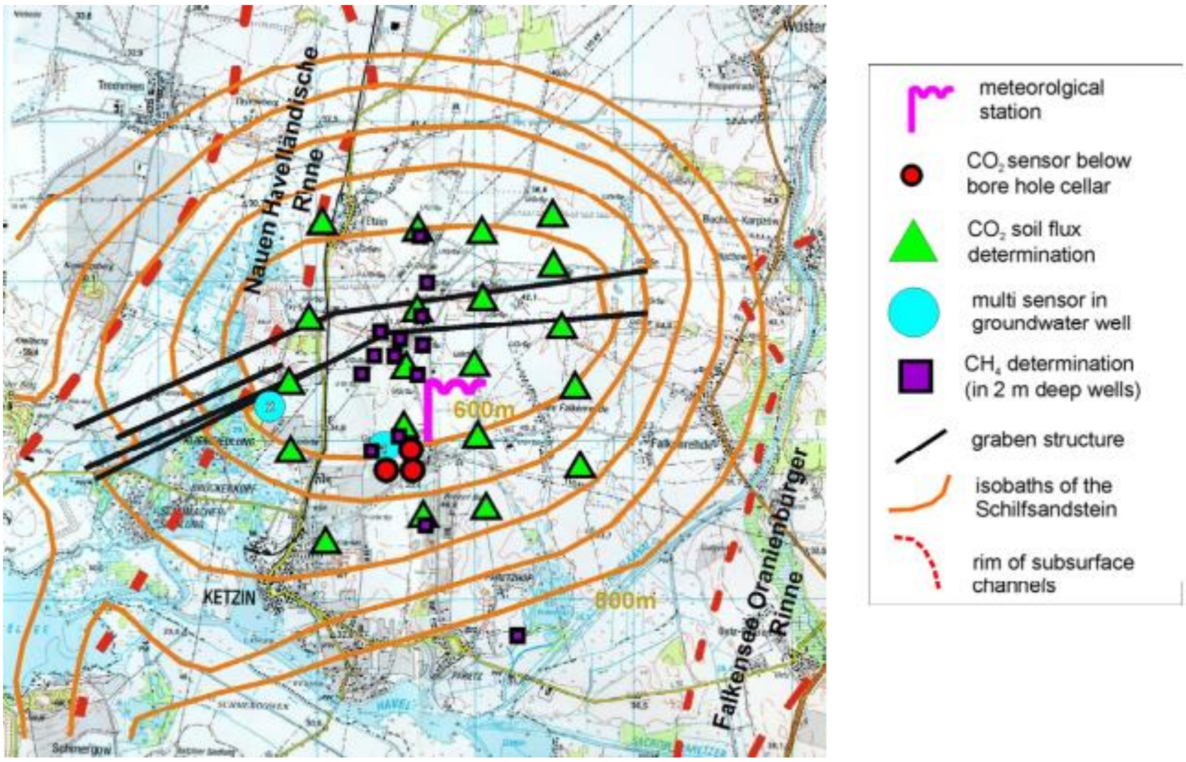

Figure 1: Surface Monitoring Network for soil CO2 Flux measurement at the Ketzin CO2 storage pilot test site

3.1. Sampling method and analytical procedure

Monitoring at the surface started in 2005 with soil CO2 flux measurements using a LI-8100 automated soil CO2 flux system (LI-COR Biosciences) and a 10-cm survey accumulation chamber. The CO2 concentration in the discharging soil gas 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 CO2 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 (Förster et al. 2006, Förster et al. 2009) and wells. In order to obtain information on seasonal trends, measurements were performed once a month. Simultaneously the soil temperature was recorded at all 20 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 CO2. As natural soil CO2 is produced via consumption of O2 during biogenic reactions and/or methane oxidation, the ratio of both gases is used for evaluation of the CO2 origin. Moreover, it is assumed that the addition of CO2 from leakage results in a physical dilution of the soil gas N2, which is not involved in biological reactions (Romanak et al. 2012, Romanak et al. 2014, Schacht and Jenkins 2014). For analyzing the composition of the soil gas phase, gas samples were taken with gas collecting glass tubes for analysis with a gas chromatograph (GC, SRI Instrument's 8610C, equipped with a silical gel and a mol sieve column and HID and TC detectors) in the laboratory. The corresponding analytical error σ was calculated for the concentration of CO2, O2 and N2 as ± 0.02, 0.01 and 0.05 %, respectively. The error resulting from the sampling procedure (possible contamination with air) for the above gases was estimated as ± 0.02, 0.19 and 0.17%, respectively.

For analyzing the δ13C isotopic composition of soil CO_2, gas samples were taken with 12 ml vials (Labco Limited) with a rubber septum. Analyses were performed at the GFZ using a GC-C-IRMS (gas chromatography /combustion /isotope ratio mass spectrometry). The system consists of a GC (6890N, Agilent Technology, USA) connected to a GC C/TC III combustion device coupled via open split to a MAT 253 mass spectrometer (ThermoFisher Scientific, Germany). The δ13C of CO_2 relative to the VPDB standard (Vienna Pee Dee Belemnite) is given in the conventional delta notation. The standard deviation σ for the isotopic measurements was ±0.5‰.

Further data of CO2 injection rates at Ketzin storage pilot test site was published in yearly operational datasets (Möller et al. 2012a-d, Möller et al. 2013, Möller et al. 2015).

Figure 2: Field application and schematics of the automated soil CO2 flux measurement system LI-8100 (LI-COR Biosciences)

4. File description

The data is stored in the zipped folder “2023-002_Zimmer-et-al_Data” and presented in 4 data tables (comma separated value file format). First a data table with the coordinates is provided followed by a table with the CO2 flux in units of micromol per square meter per second [µmol m-2 s-1]. Every row represents monthly CO2 flux measurement with given date for the measurement period 2005-2016. Labeled columns represents the 20 positions of the soil CO2 measurement network.

In addition, a table with coordinates of the measurement network positions, a table with soil moisture in [%] and a table with soil temperature in [°C] for each monitoring position is given. Additionally, all excel sheets are stored as tab delimited text files, too:

- 2023-002_Zimmer-et-al_Data_coordinates.txt
- 2023-002_Zimmer-et-al_Data_CO2-flux_2005-2016.txt
- 2023-002_Zimmer-et-al_Data_Soil-moisture_2005-2016.txt
- 2023-002_Zimmer-et-al_Data_Soil-temperatures_2005-2016.txt

CO_2flux [µmol/ m^2 s] in the Ketzin area

	latitude	N 52°29'23,0"	N 52°29'59,8"	N 52°30'28,8"	N 52°31'05,2"	N 52°31'03,3"	N 52°30'29,5"	N 52°30'07,4"	N 52°29'39,2"	N 52°29'39,7"	N 52°30'11,1"	N 52°30'33,1"	N 52°31'05,7"
	longitude	E 12°50'54,0"	E 12°50'52,2"	E 12°51'05,1"	E 12°50'54,9"	E 12°52'17,1"	E 12°52'09,1"	E 12°52'05,9"	E 12°52'05,9"	E 12°52'51,6"	E 12°52'52,4"	E 12°52'54,8"	E 12°52'58,4"
year	date	Pos. 01	Pos. 02	Pos. 03	Pos. 04	Pos. 05	Pos. 06	Pos. 07	Pos. 08	Pos. 09	Pos. 10	Pos. 11	Pos. 12
	01.01.2005												
2005	14.01.2005	3,00	1,11	1,12	3,25	1,45	0,94	0,59	0,44	1,16	1,77	1,03	0,58
	04.02.2005	2,74	0,52	0,98	0,78	0,63	0,76	0,42	0,31	0,52	0,68	0,92	0,56
	01.03.2005	0,45	0,17	0,55	0,55	0,97	0,31	0,38	0,31	0,35	4,20	0,38	0,40
	05.04.2005	0,65	0,65	1,15	0,86	1,37	0,57	0,81	0,26	1,57	2,46	1,41	0,82
	26.04.2005	0,86	0,98	0,49	2,30	1,26	0,26	0,80	0,55	2,84	3,80	1,21	1,50
	23.05.2005	2,20	2,04	1,00	5,50	3,39	0,87	3,67	0,45	3,40	7,75	0,64	1,92
	23.06.2005	10,0	2,91	1,74	6,07	5,12	0,94	2,21	1,19	7,64	6,41	7,10	2,18
	26.07.2005	8,00	2,05	1,55	5,30	4,60	0,98	1,36	1,58	4,35	3,66	1,71	1,75
	30.08.2005	10,3	4,00	2,65	10,85	4,70	1,32	4,85	2,20	7,35	5,52	4,05	3,25
	06.10.2005	6,35	2,53	1,60	9,17	2,59	0,93	3,52	1,42	3,54	3,54	1,71	4,85
	02.11.2005	4,98	1,80	1,34	6,19	2,89	0,73	2,57	0,90	3,27	2,39	1,48	2,25
	06.12.2005	1,4	1,25	0,53	0,9	0,74	0,19	1,5	0,2	1,6	1,5	0,6	0,65
2006	05.01.2006	0,37	0,87	0,32	1,35	0,35	0,01	0,01	0,40	0,10	3,10	0,10	1,19
	08.02.2006	0,19	0,18	0,33	0,45	0,01	0,01	0,36	0,07	0,52	0,24	0,44	0,6
	13.03.2006	0,74	0,96	0,64	0,70	1,76	0,11	0,35	0,26	1,37	2,94	1,21	0,38
	18.04.2006	1,65	0,82	1,71	3,67	2,81	0,23	1,40	0,66	1,14	1,36	1,06	2,30
	18.05.2006	6,30	3,46	2,86	7,37	10,0	0,99	2,27	2,28	1,90	5,90	5,40	3,83
	28.06.2006	5,90	3,60	4,60	6,50	14,70	1,05	5,30	2,38	5,00	5,58	4,50	2,63
	09.08.2006	8,35	3,55	3,60	8,30	9,45	1,25	5,75	4,60	3,80	5,80	3,30	5,50
	28.09.2006	13,1	6,26	11,1	15,0	7,50	2,08	5,17	1,93	7,94	3,65	5,00	3,30
	24.10.2006	6,70	2,34	3,95	5,65	10,50	2,00	3,95	1,13	2,23	2,48	2,15	1,50
	07.11.2006	2,15	1,92	3,34	3,85	2,22	1,00	3,95	0,70	1,44	1,54	1,70	2,00
	06.12.2006	3,90	2,06	1,60	2,30	3,30	0,90	3,74	0,28	1,57	1,64	1,71	1,10
2007	24.01.2007	0,63	0,88	0,52	0,69	0,75	0,35	0,46	0,51	0,48	0,95	0,59	0,61
	28.02.2007	1,99	1,17	0,7	1,65	8,53	0,21	0,36	0,59	0,55	1,16	0,96	1,21
	29.03.2007	2,62	1,55	0,71	1,23	4,20	0,74	0,81	1,50	2,5	0,83	0,66	3,65
	26.04.2007	4,15	3,10	2,45	4,15	4,58	1,75	2,97	1,53	4,17	3,39	2,71	4,80
	29.05.2007	6,81	7,40	7,31	6,10	4,80	6,37	2,60	2,40	6,30	6,57	3,05	5,70
	29.06.2007	5,63	8,79	10,6	5,64	5,05	2,80	3,45	1,60	8,57	10,4	14,7	4,13

coordinates | flux | soil moisture | soil temperature

Figure 3: Excerpt from the soil CO2 flux monitoring data table

5. References

Förster, A., Norden, B., Zinck Jørgensen, K., Frykman, P., Kulenkampff, J., Spangenberg, E., Erzinger, J., Zimmer M., Kopp, J., Borm, G.,Juhlin, C., Cosma, C., Hurter, S. (2006). Baseline characterization of the CO2SINK geological storage site at Ketzin, Germany. Environmental Geosciences 13, https://doi.org/10.1306/eg.02080605016

Förster, A., Giese, R., Juhlin, C., Norden, B., Springer, N., CO2SINK Group (2009). The Geology of the CO2SINK Site: From Regional Scale to Laboratory Scale. Energy Procedia 1, https://doi.org/10.1016/j.egypro.2009.02.066

Martens, S., Möller, F., Streibel, M., Liebscher, A. and the Ketzin Group (2014). Completion of five years of safe CO2 injection and transition to the post-closure phase at the Ketzin pilot site. Energy Procedia 59, 190-197, https://doi.org/10.1016/j.egypro.2014.10.366

Martens, S., Conze, R., De Lucia, M., Henninges, J., Kempka, T., Liebscher, A., Lüth, S., Möller, F., Norden, B., Prevedel, B., Schmidt-Hattenberger, C., Szizybalski, A., Vieth-Hillebrand, A., Würdemann, H., Zemke, K., Zimmer, M. (2015). Joint Research Project CO2MAN (CO2MAN Reservoir Management): Continuation of Research and Development Work for CO2 Storage at the Ketzin Pilot Site. In; A. Liebscher and U. Münch (eds.), Geological Storage of CO2 - Long Term Security Aspects, Advanced Technologies in Earth Sciences, Springer International Publishing Switzerland, 1-32, https://doi.org/10.1007/978-3-319-13930-2_1

Möller, F.; Liebscher, A.; Martens, S.; Schmidt-Hattenberger, C.; Kühn, M. (2012a): Supplement 2008 to: F. Möller, A. Liebscher, S. Martens, C. Schmidt-Hattenberger, M. Kühn: Yearly Operational Datasets of the CO2 Storage Pilot Site Ketzin, Germany. Deutsches GeoForschungsZentrum GFZ. https://doi.org/10.5880/GFZ.b103-12066.2008

Möller, F.; Liebscher, A.; Martens, S.; Schmidt-Hattenberger, C.; Kühn, M. (2012b): Supplement 2009 to: F. Möller, A. Liebscher, S. Martens, C. Schmidt-Hattenberger, M. Kühn: Yearly Operational Datasets of the CO2 Storage Pilot Site Ketzin, Germany. Deutsches GeoForschungsZentrum GFZ. https://doi.org/10.5880/GFZ.b103-12066.2009

Möller, F.; Liebscher, A.; Martens, S.; Schmidt-Hattenberger, C.; Kühn, M. (2012c): Supplement 2010 to: F. Möller, A. Liebscher, S. Martens, C. Schmidt-Hattenberger, M. Kühn: Yearly Operational Datasets of the CO2 Storage Pilot Site Ketzin, Germany. Deutsches GeoForschungsZentrum GFZ. https://doi.org/10.5880/GFZ.b103-12066.2010

Möller, F.; Liebscher, A.; Martens, S.; Schmidt-Hattenberger, C.; Kühn, M. (2012d): Supplement 2011 to: F. Möller, A. Liebscher, S. Martens, C. Schmidt-Hattenberger, M. Kühn: Yearly Operational Datasets of the CO2 Storage Pilot Site Ketzin, Germany. Deutsches GeoForschungsZentrum GFZ. https://doi.org/10.5880/GFZ.b103-12066.2011

Möller, F.; Liebscher, A.; Martens, S.; Schmidt-Hattenberger, C.; Kühn, M. (2013): Supplement 2012 to: F. Möller, A. Liebscher, S. Martens, C. Schmidt-Hattenberger, M. Kühn: Yearly Operational Datasets of the CO2 Storage Pilot Site Ketzin, Germany. Deutsches GeoForschungsZentrum GFZ. https://doi.org/10.5880/GFZ.b103-12066.2012

Möller, F.; Liebscher, A.; Martens, S.; Schmidt-Hattenberger, C.; Kühn, M. (2015): Supplement 2013 to: F. Möller, A. Liebscher, S. Martens, C. Schmidt-Hattenberger, M. Kühn: Yearly Operational Datasets of the CO2 Storage Pilot Site Ketzin, Germany. Deutsches GeoForschungsZentrum GFZ. https://doi.org/10.5880/GFZ.b103-12066.2013

Romanak, K.D., Bennett, P.C., Yang, C., Hovorka, S.D. (2012). Process-based approach to CO2 leakage detection by vadose zone gas monitoring at geologic CO2 storage sites. Geophysical Research Letters 39, https://doi.org/10.1029/2012GL052426

Romanak, K.D., Wolaver, B., Yang, C., Sherk, G.W., Dale, J., Dobeck, L.M., Spangler, L.H. (2014). Process-based soil gas leakage assessment at the Kerr Farm: Comparison of results to leakage proxies at ZERT and Mt. Etna. International Journal of Greenhouse Gas Control 30, https://doi.org/10.1016/j.ijggc.2014.08.008

Schacht, U., Jenkins, C. (2014). Soil gas monitoring of the Otway Project demonstration site in SE Victoria, Australia. International Journal of Greenhouse Gas Control 24, 14–29, https://doi.org/10.1016/j.ijggc.2014.02.007

Wipki, M., Ivanova, A., Liebscher, A., Lüth, S., Möller, F., Szizybalski, A., Wiese, B. and Zimmer, M. (2016). Monitoring Concept for CO2 Storage at the Ketzin Pilot Site,Germany – post injection continuation towards transfer of liability. Energy Procedia 97, https://doi.org10.1016/j.egypro.2016.10.017

Zimmer, M., Pilz, P., & Erzinger, J. (2011). Long-term surface carbon dioxide flux monitoring at the Ketzin carbon dioxide storage test site. Environmental Geosciences, 18(2), 119-130, https://doi.org/10.1306/eg.11181010017