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Soil gas monitoring experience from above underground gas storage and a pilot CO_2 storage, Czechia

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Introduction

Both oil & gas fields and underground gas storages (UGS) require periodical check of the trap integrity. The soil gas geochemistry and monitoring were used for this purpose. The (1) **Zar-3 oil & gas field** located in SE Czechia is a potential candidate for **CO_2 storage pilot**. The field was discovered in 2001, at present it is in the final production phase. The (2) **Zukov gas field** located in NE Czechia was explored in the 1950s and, in 2001, converted to **UGS**. Over 50 deep boreholes were drilled there, some of them have been identified as risky for possible gas leakage. In both Zar-3 and Zukov fields, soil gas monitoring was carried out for more than 2 years to distinguish the natural variability and to establish the threshold values that could indicate potential gas leakage.

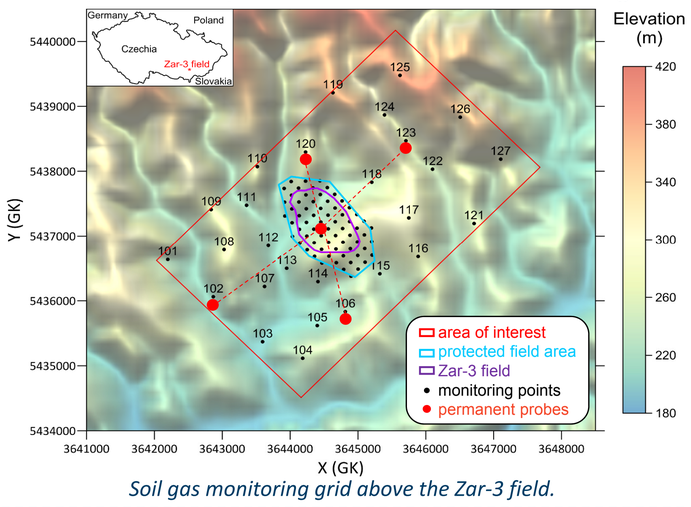
Objectives

- Periodical check of the trap integrity
- Identify potential soil gas **anomalies**
- Define **seasonal, climatic and soil** type controls on changes in soil gas CO_2 content and CH_4 flux
- Evaluation of the **gas origin** based on chemical and **isotopic** composition
- **Baseline** monitoring showing the pre-storage pattern of CO_2 content in soil gas

Soil gas monitoring grid

Zar-3 field:

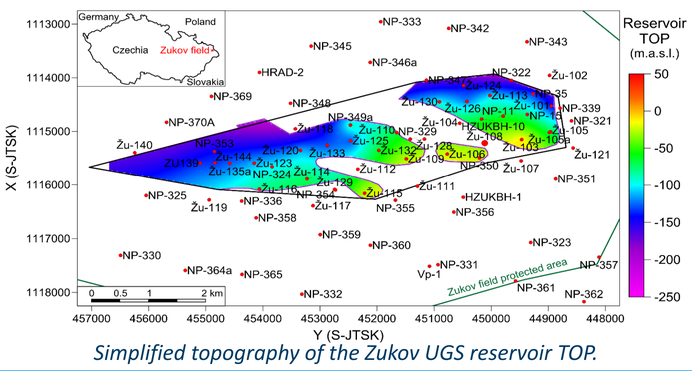
- 95 points for periodical monitoring
- 5 permanent probes for continuous monitoring



Soil gas monitoring grid above the Zar-3 field.

Zukov field:

- Up to 41 points for periodical monitoring above each of selected wells (e.g. Zu-108, -110, -139,..)



Simplified topography of the Zukov UGS reservoir TOP.

Soil gas methods

Periodical monitoring using portable spectral inst.:

- Ecoprobe-5™ evaluates content of CO_2, CH_4 and O_2
- Measured at soil depth of 80 cm
- 3x / year at Zar-3 field, monthly at Zukov field

Continuous monitoring at Zar-3 field:

- 5 diffusion spectral probes for CO_2 monitoring
- Continuously since June 2021 till present
- Buried 80 cm below the ground surface

Gas chromatography – periodical at both fields:

- IRMS carbon isotopic composition

+ Soil gas flux at Zukov field (accumulation chamber)

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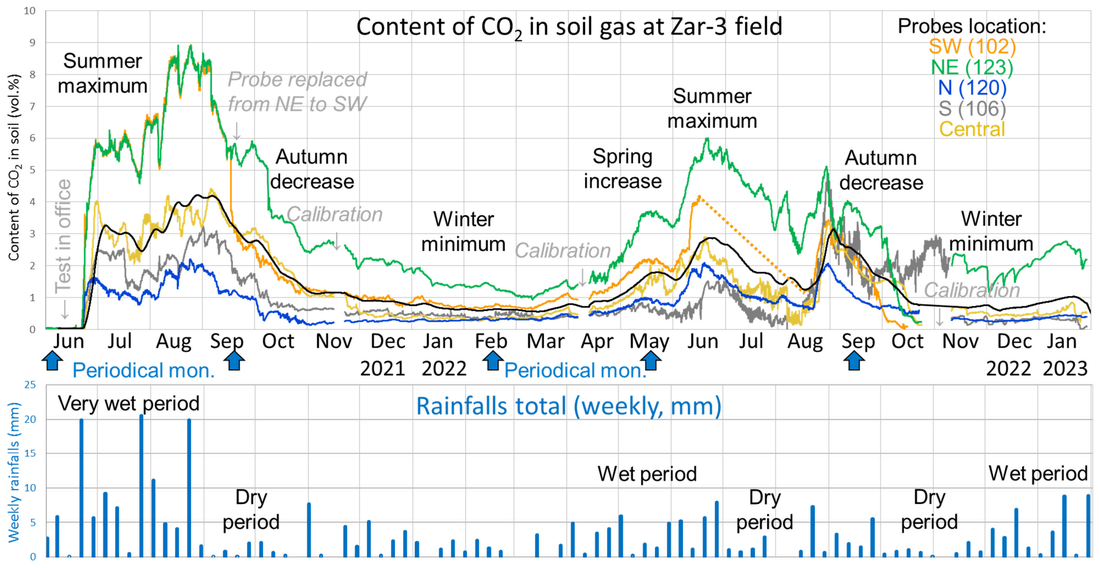
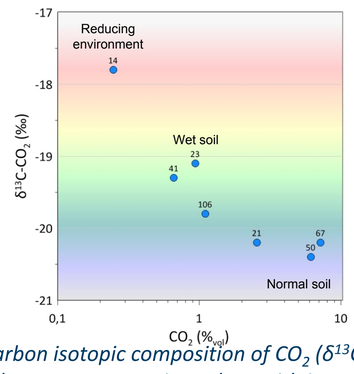
Results and discussion

Zar-3 field – baseline monitoring and soil gas pattern:

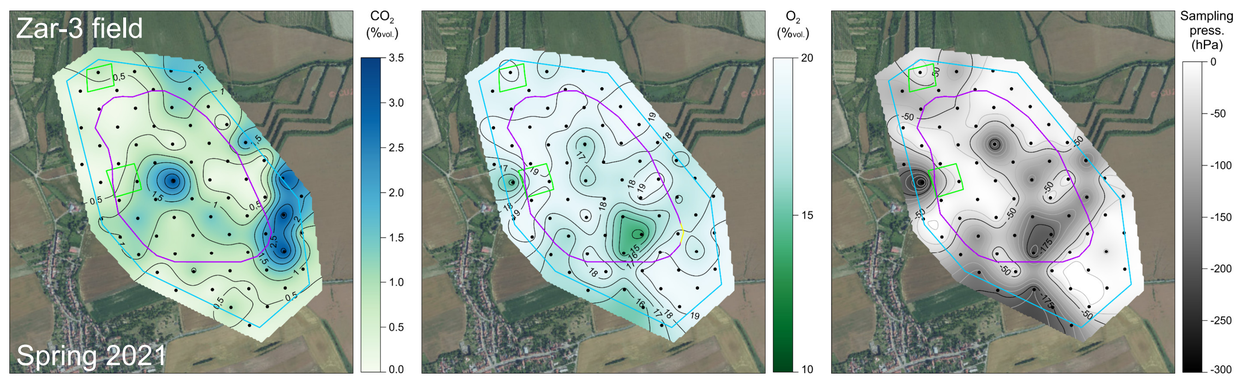
- Strong soil gas compositional variability registered by continuous CO_2 probes provides evidence of influence by **temperature** (season of the year), **biological activity** and **soil wetness**
- The effect of **atmospheric pressure** on CO_2 content in soil gas was found to be matter of hours or days (daily variations); atmospheric **pressure drops** are more important than its absolute value
- **Land-use factors:** the grasslands and forests show more stable soil gas composition when compared to cultivated fields. Ploughing the fields increases the permeability and soil gas - atmosphere communication



Time-plot of CO_2 content in soil gas measured by five permanent probes (in colors) related to the rainfalls total (bottom). Maximum CO_2 content in soil gas was measured in summer seasons and during and after strong rainfalls.



Carbon isotopic composition of CO_2 ($\delta^{13}C$-CO_2) shows more negative values with increasing CO_2 content in soil gas.



Contour maps of the average CO_2 and O_2 content in soil gas (both in $\%_{vol}$) and sampling pressure (hPa) in spring 2021. Effects of land use - field ploughing - is clearly visible in SE part of the monitored area.

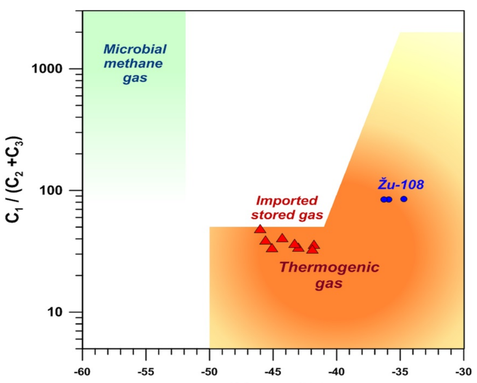
Polygons: cyan = field protected area, purple = Zar-3 field, green = drilling platforms.

Zukov field – poorly abandoned borehole Zu-108:

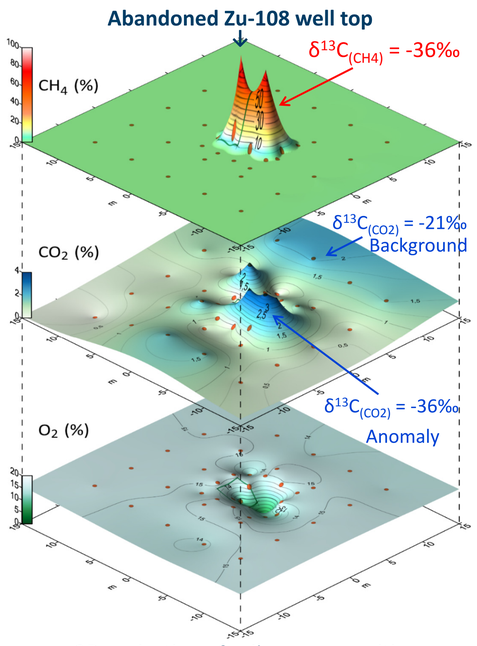
- Typical soil gas pattern: **high CH_4 anomaly** (10-60%$_{vol}$), surrounding **CO_2 collar** and significant **O_2 drop**; methane plume anomaly is in most cases < 10 m in diameter
- High CH_4 flux ranging up to **26 197 g $d^{-1}m^{-2}$** was measured directly above the well
- High flux was observed during low atm. pressure periods and when the soil water level was low; lowest flux was observed after strong rainfalls or when the soil was frozen

Chemical and isotopic composition at Zu-108, Zukov field:

- **CH_4** is of **thermogenic** origin related to gas in small gas fields, **UGS leakage ruled out**
- CO_2 in natural background is of **plant** roots respiration
- CO_2 restricted to CH_4 anomaly is from **microbial oxidation of CH_4** ($\delta^{13}C_{(CO2)}$ = -36‰)
- Observed **controls** of absolute CH_4 and CO_2 content are **atmospheric pressure**, ground **water level**, soil **wetness** and **temperature**
- Seasonal periodicity was confirmed – highest anomalies in wet spring and autumn versus low values in dry summer and frozen winter



The $\delta^{13}C_{(CH4)}$ and gas dryness ratio $C_1/(C_2+C_3)$ showing the Zu-108 soil gas and imported stored gas type in the UGS.



3D projection of soil gas composition above Zu-108 well.

Conclusions

- The results of the monitoring campaigns provide examples of **CH_4, CO_2 and O_2 anomalies in soil gas**
- Mapping the data show **relationships** to **morphology, ground water level** and **flow, atmospheric pressure** & **temperature, soil wetness** & **permeability** and mainly to the **precipitations**
- Chemical and isotopic composition of the gas samples shows that permanent slow methane flux generates **microbial colonies oxidizing CH_4 to CO_2** with very negative values of $\delta^{13}C$
- The measured and interpreted data show examples of settings, where **CO_2 from methane** ($\delta^{13}C_{(CO2)}$ = -36‰) is **distinguished** from that of **plant roots origin** ($\delta^{13}C_{(CO2)}$ = -21‰)