Investigating well testing as a monitoring technique for a CO_2 plume geothermal

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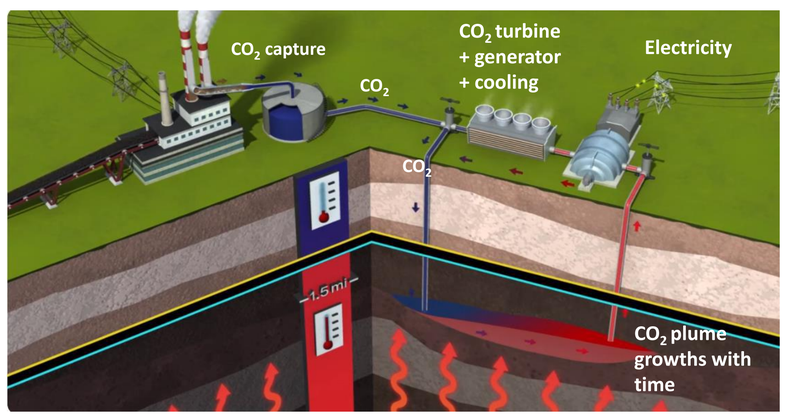
CO_2 Plume Geothermal (CPG)

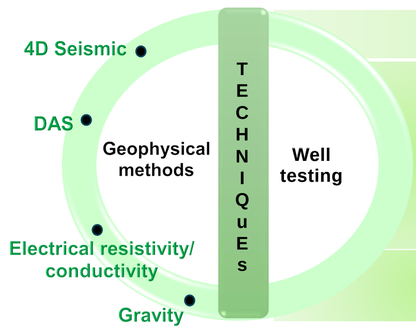


Schematic of CO_2 plume geothermal in the video of CPG provided by GEG Group, ETH Zurich. (https://www.youtube.com/watch?v=x7fPNLY6h0U).

Gigatonne scale geological storage of CO_2 and green energy provisions are the main aspects of a sustainable energy future. CO_2 Plume Geothermal is one of the technologies that can mitigate CO_2 emissions and provide renewable geothermal energy with CO_2 as the working fluid. (Adam et al., 2014). The CO_2 is circulated through naturally permeable formations, resulting in a large-scale CO_2 plume. As such, understanding the CO_2 plume behavior is crucial for forecasting (the start of) electricity production. It underlines the importance of monitoring CO_2 plume behavior during and after short- and long-term injection periods.

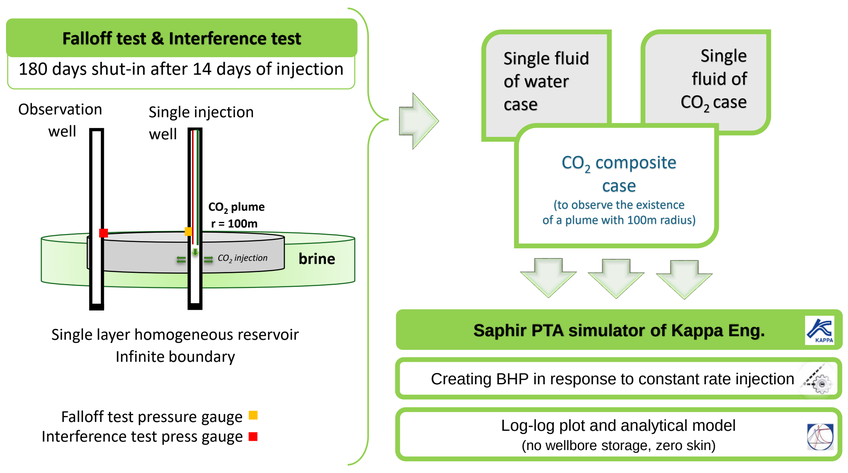
CO_2 plume monitoring in CCS

The cost in monitoring CO_2 can range from $10,000s (for routine operational pressure/temperature monitoring) to $1,000,000s (for 4D seismic methods) (IEAGHG Technical Report, 2020). The use of well-testing a cost-efficient additional monitoring technique.



	Matching the model to the data allows **to determine subsurface properties**
Falloff test	Fluid flow properties such as mobilities, extent of dry-out zone, **extent of plume**, and two-phase zone (Abdelaal and Zeidouni, 2020)
	The reservoir's permeability and the effective compressibility in AEP's Mountaineer CO_2 Plant, West Virginia, USA (Mishra et al., (2013)
	The flow barriers near the well in Snøhvit field (Hansen et al, 2013)
Interference test	Permeability and formation compressibility in Frio brine formation, USA Gulf coast (Doughty et al, 2008)

Kappa-Saphire well testing application



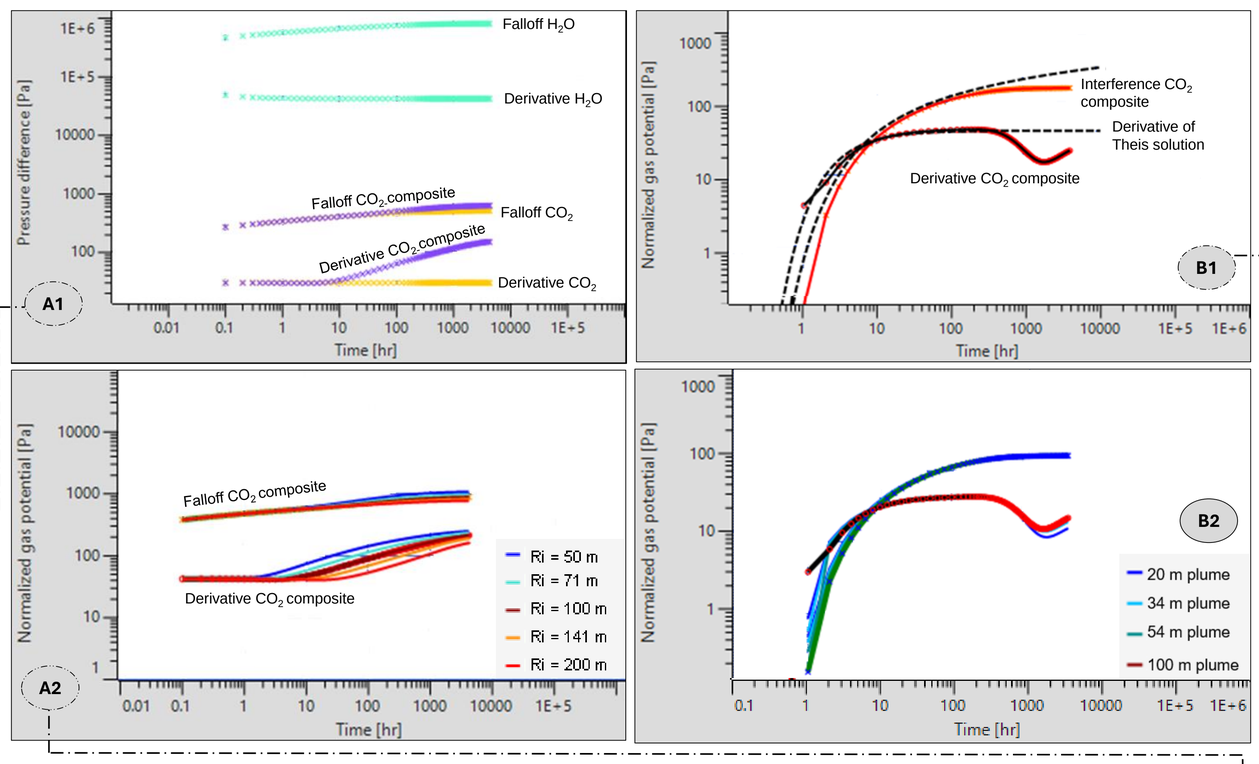
In order to answer the main question: "Can well testing be used as a CO_2 plume surveillance method for CO_2-Plume Geothermal (CPG), and what recommendations can be made for its use in a CPG field demonstration? ";

We have utilized the falloff and interference testing methods for three distinct injection cases. However, it's crucial to acknowledge that we have made certain neglectful assumptions, including the exclusion of gravity and capillary forces, the two-phase zone where CO_2 and brine are mixing, the geochemical reactions in the system, and isothermal flow with constant density and compressibility. Additionally, it's important to note that the models do not incorporate geological faults.

Falloff test and interference test results

The log-log plot in Figure A1 shows that the composite model's pressure falloff and pressure derivative overlap with the single fluid-CO_2 model initially, which is the area of infinite-acting radial flow. The radial flow of the CO_2 plume with a 100 m radius is observed until 6 h of shut-in, and the pressure derivative of the CO_2-composite model goes up until the end of injection time, representing a transient flow regime of the plume.

We conduct the sensitivity analysis to evaluate if the resulting pressure difference and the pressure derivative in the log-log plot allow distinguishing different plume sizes (Figure A2).



It indicates how an increased CO_2 plume size shifts the pressure falloff and the pressure derivative down. The derivative line of the transient flow regime for 50 m, 100 m, and 200m plume size started to be seen at 1h,6h, and 30h after shut-in, respectively. Therefore, the falloff pressure analysis helps distinguish the derivative signature of different plume sizes.

The log-log plot in Figure B1 for well distance 100 m shows an inflection points at the time-lapse of 8 hours. The zero-slope line corresponding to the radial flow regime of the CO_2 plume clearly observed at 8 hours to 350 h after inflection point. Moreover, the interference response does overlap on the exponential integral Theis solution.

The sensitivity analysis of interference response in Figure B2 illustrates that the discrepancy between the time lapse of plume sizes less than 100 m was observed simultaneously. Thus, interference response can provide information about the existence of CO_2 plume with a certain size.

Conclusions

- ✓ The falloff test shows that the log-log curve of the CO2 composite model can provide the feature of a CO2 plume existence with a 100 m radius.
- ✓ Sensitivity analysis shows that different plume sizes result in distinct pressure arrival times; the more significant the size, the longer the time required.
- ✓ The falloff response can be observed in the interference well testing.