2nd European Underground Energy Storage Workshop

Mass exchanges between the salt cavern phases : Gas dissolution in the brine

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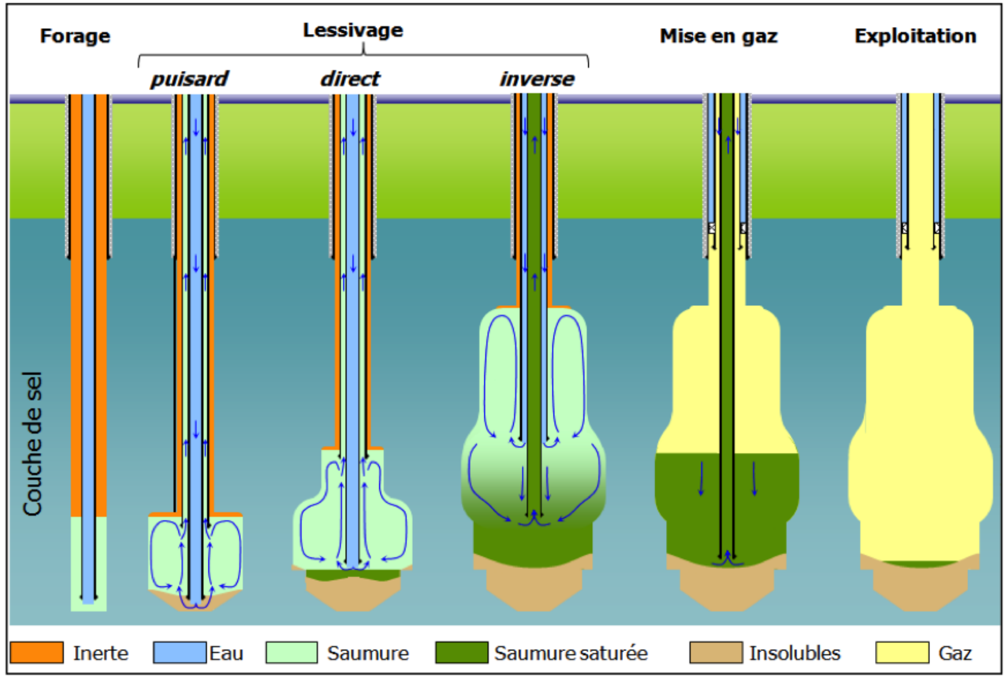
Energy transition: Gas storage in salt caverns is used to balance between the offer and the demand



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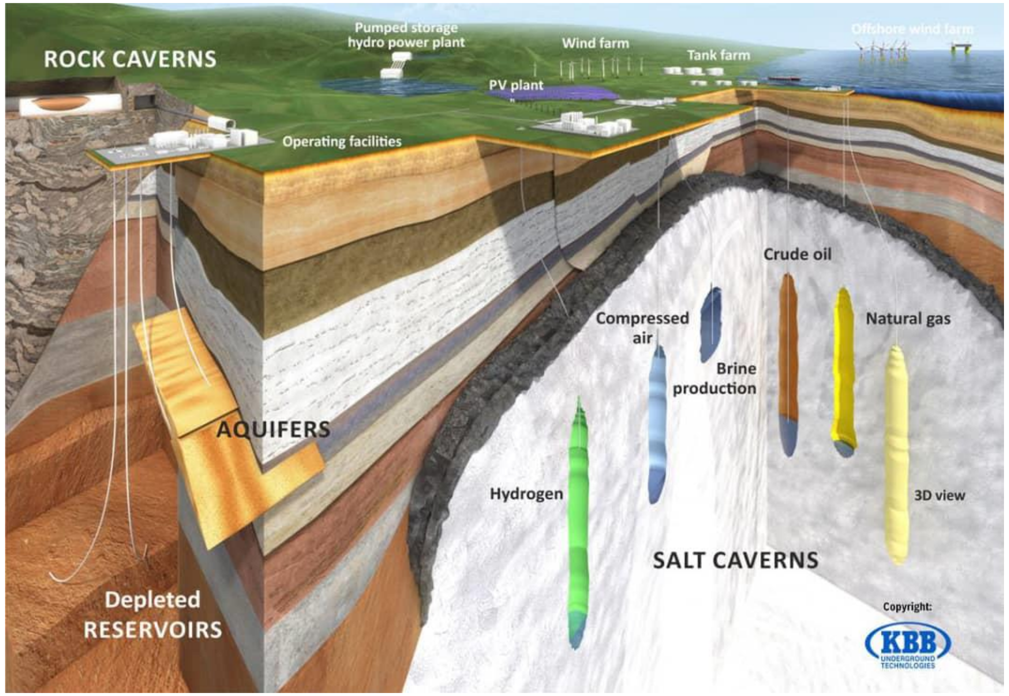


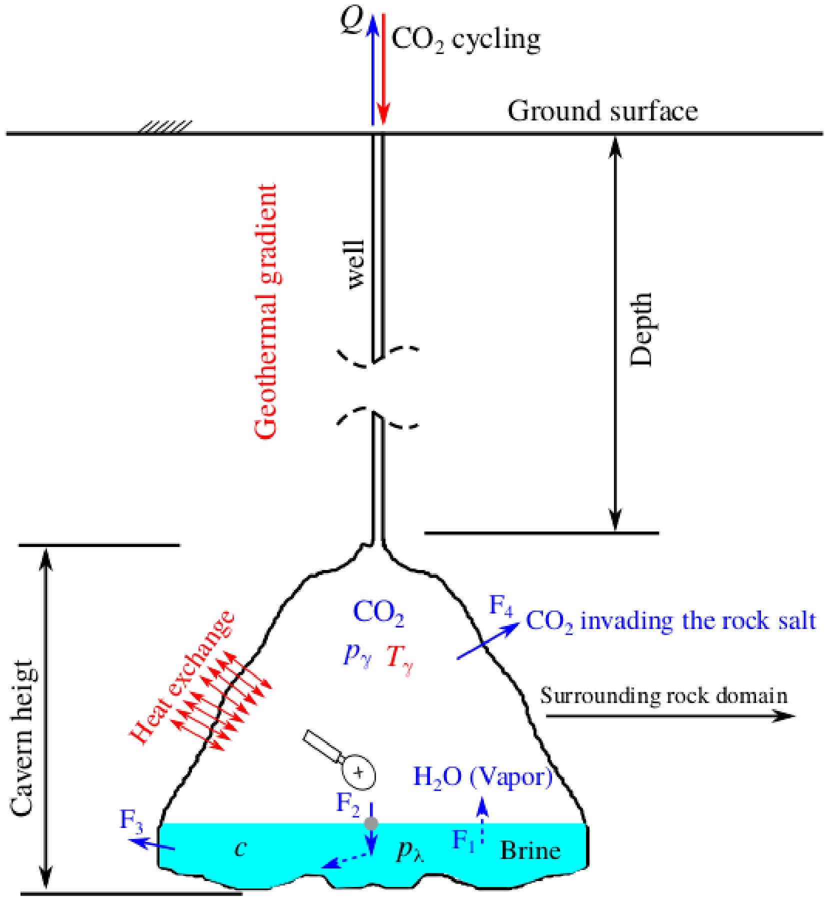
As a means to store gas: Low investment cost and low cushion gas

Good records and management of the cycled gas quantities (price in case of H_2)

Gas dissolution in the cavern brine (flux F_2)

Example: Carbon dioxide (CO_2)

The developed numerical model is general and can be used for any gas



Underground salt cavern

p_γ : CO_2 pressure in the cavern

T_γ : CO_2 temperature in the cavern

T_σ : Rock domain temperature

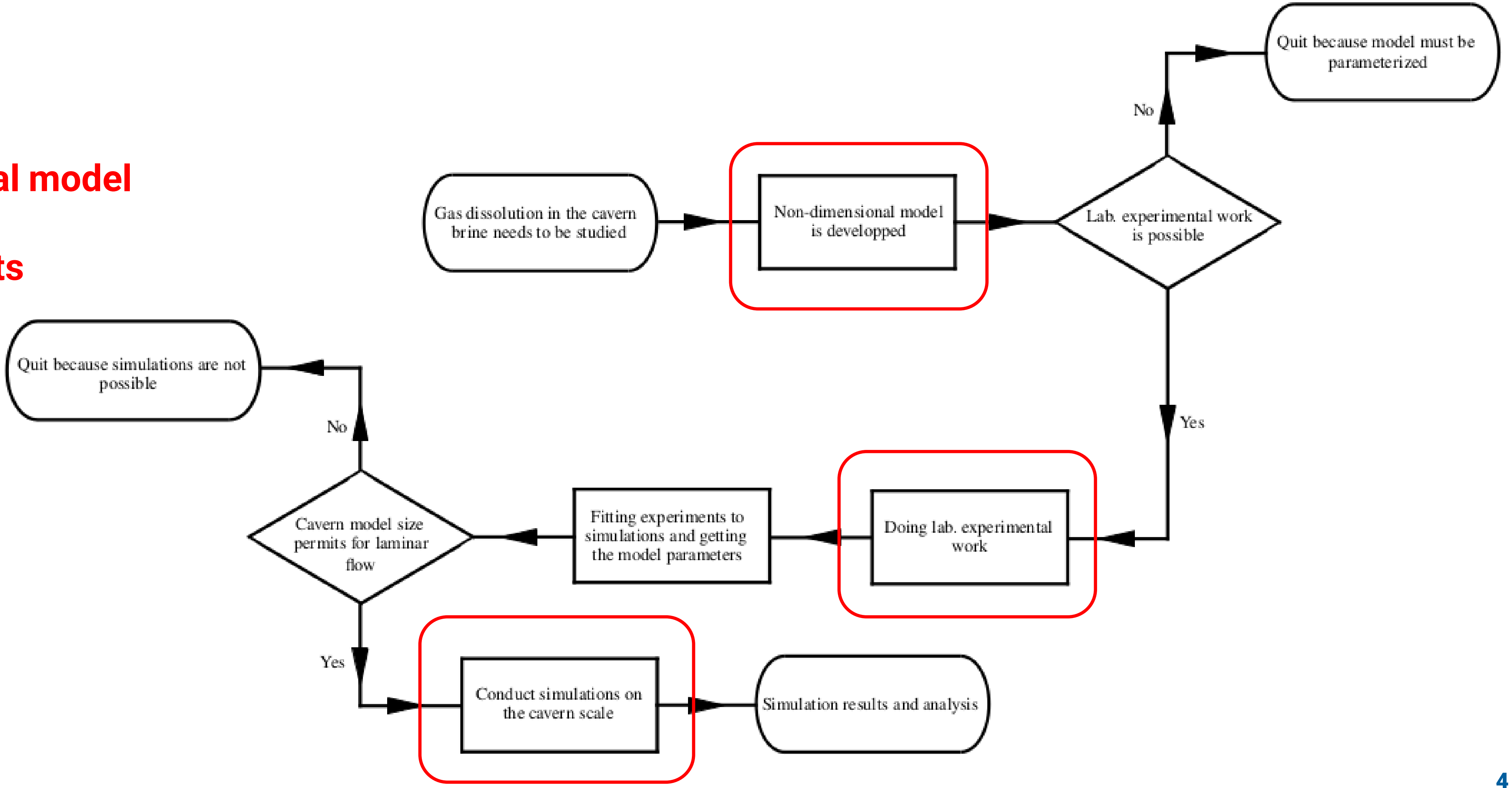
p_λ : Brine pressure in the cavern

c : CO_2 mass concentration in the brine

A non–dimensional model to study the kinetics of CO_2 dissolution in brine from the laboratory to the salt cavern scale

A non–dimensional model

The thermal effects



Components of the mathematical non-dimensional model

The cavern part

1- The thermodynamic state (p, T)

2- gas state law

The liquid part

1- density changes due to the dissolution and temperature gradient

2- Navier-Stokes equation

3- liquid state law

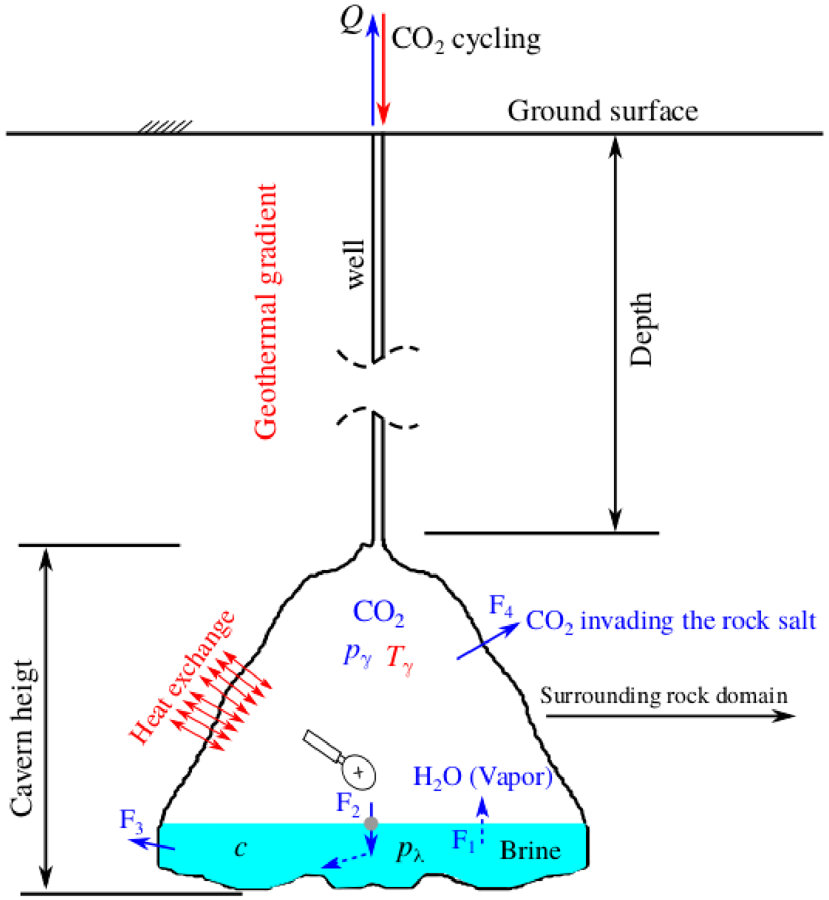
The liquid-gas interface

1- heat exchange

2- gas/mass exchange

The rock salt part

1- heat transfer



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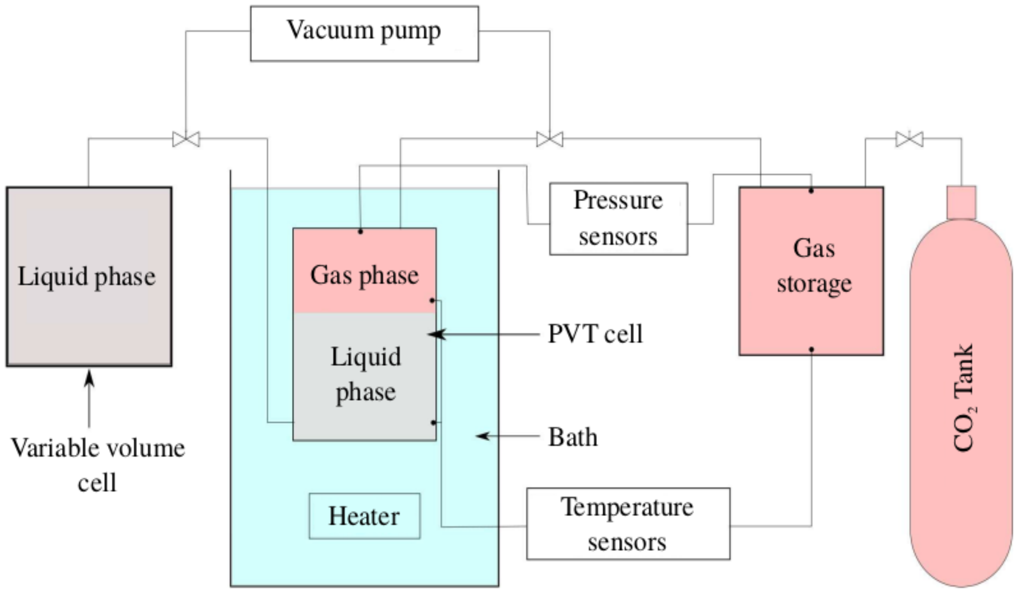
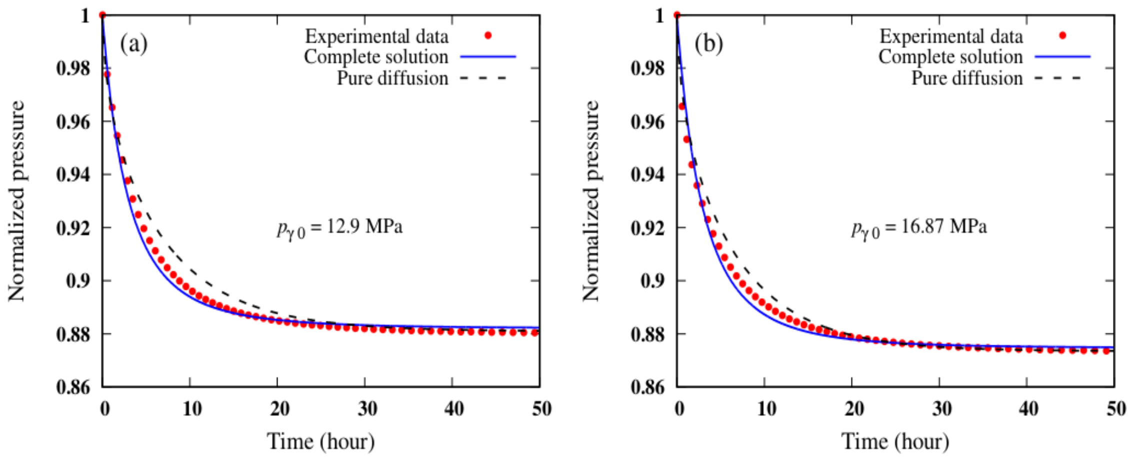
Validation on the lab. scale

Schematic representation of the pressure decay PVT cell. The CO_2 is in the super critical state, isothermal test conditions, T = 40 °C.



A comparison between the numerical and the experimental pressure histories for the two laboratory tests.



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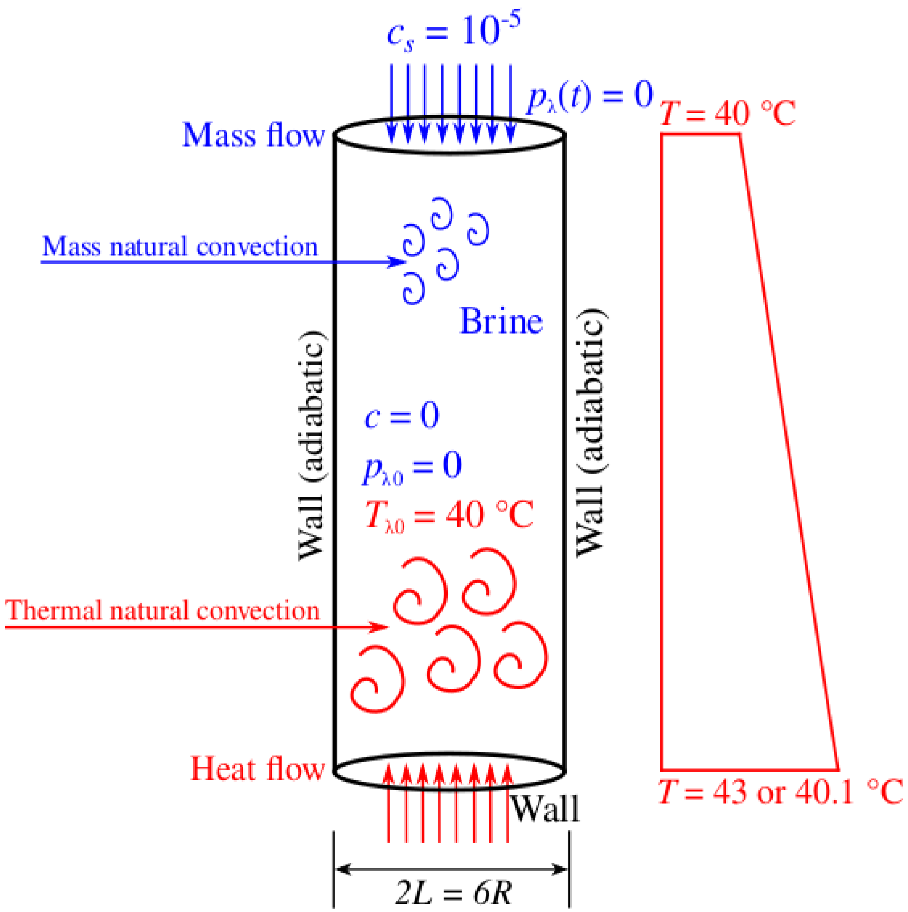
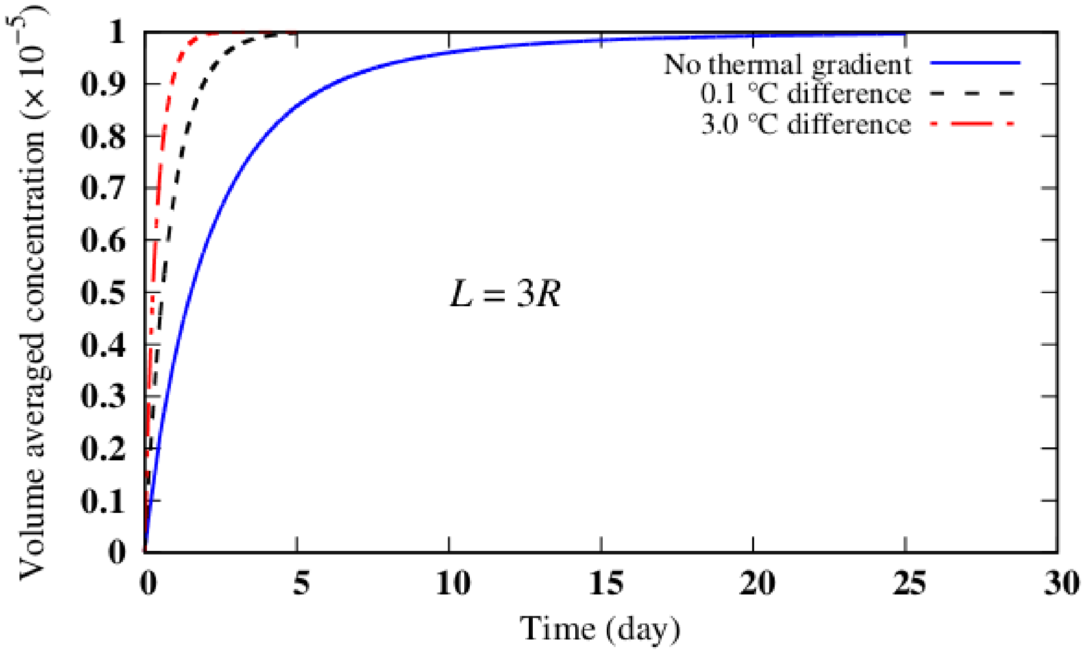
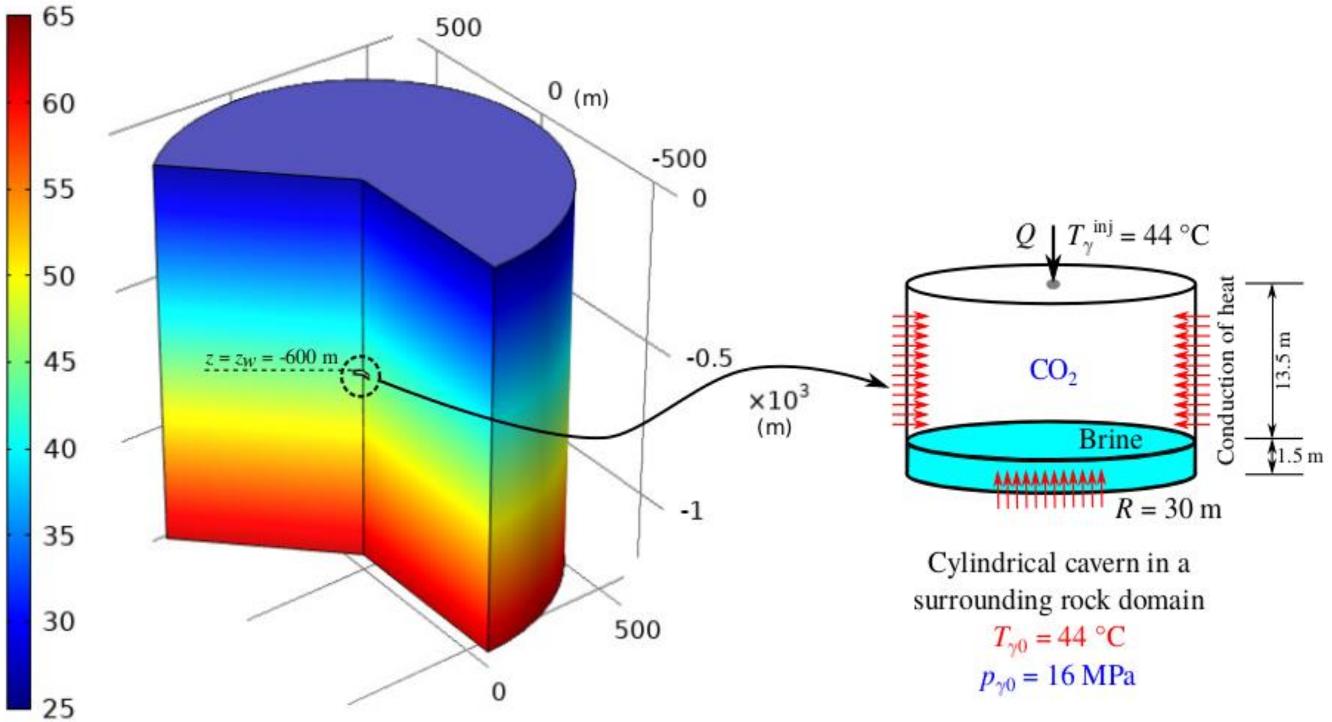
Quantification of thermal effects on the kinetics of dissolution (Numerical quantification)



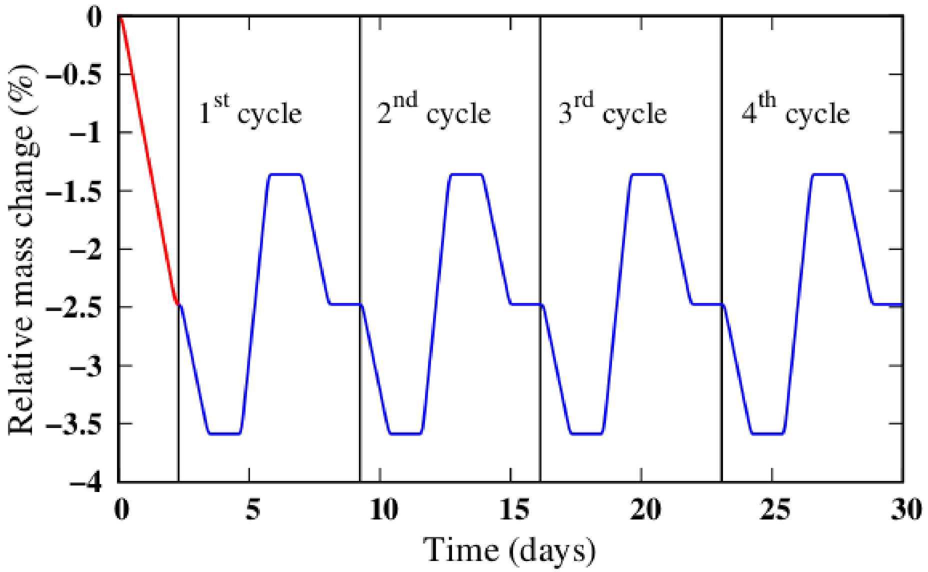


Evolution of the volume averaged CO_2 concentration with the *L* = 3*R* model. The figure shows how the thermal effects due to different gradients accelerate considerably the dissolution process.

A cylindrical cavern created at depth of 600 m in a surrounding rock salt domain. The geothermal gradient gives a cavern volume averaged temperature of 44 °C. The cavern is assumed initially full of real CO_2 at a pressure of 16 MPa.



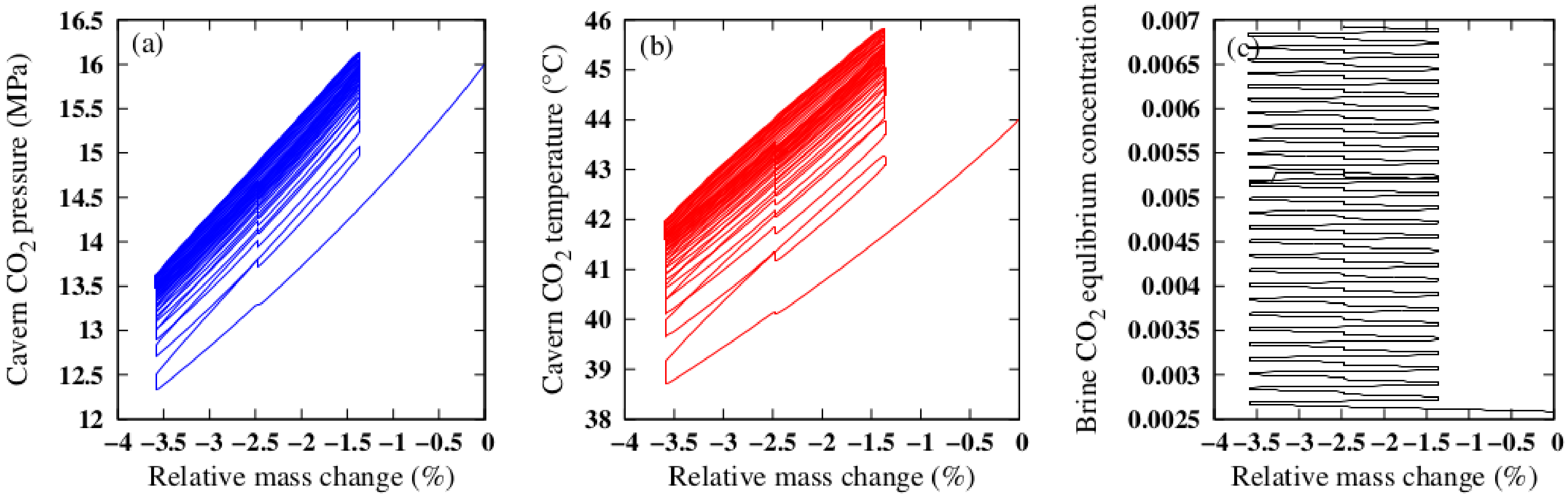
Geothermal temperature:
$T_{\sigma\infty}$(°C) = 26 - 0.03 z (m)

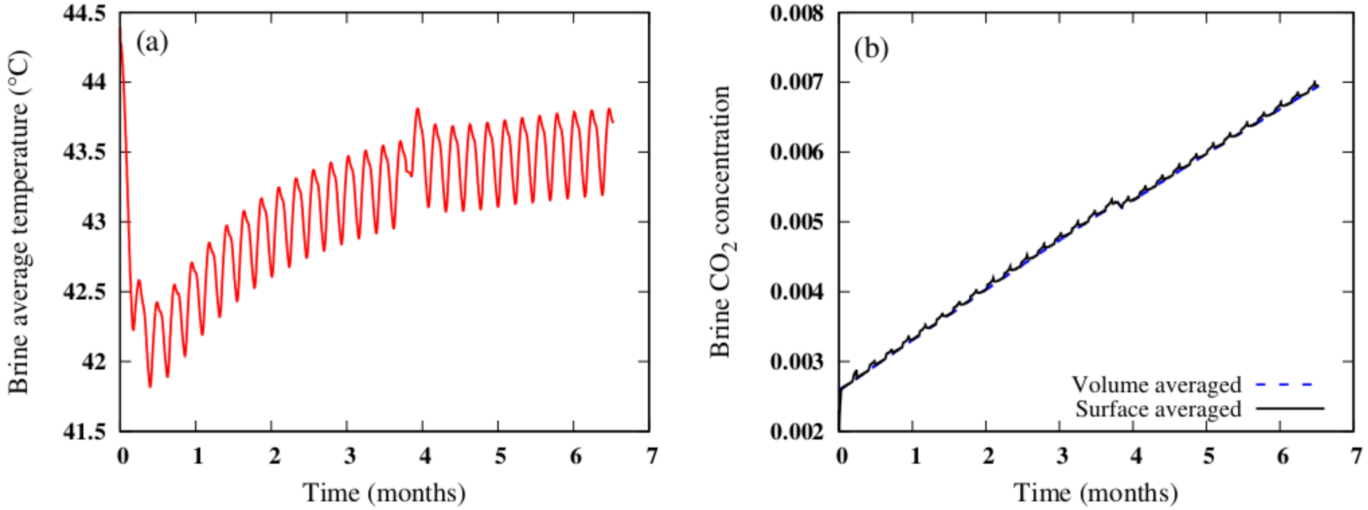


Cycling during 6.5 moths (~26 cycles)

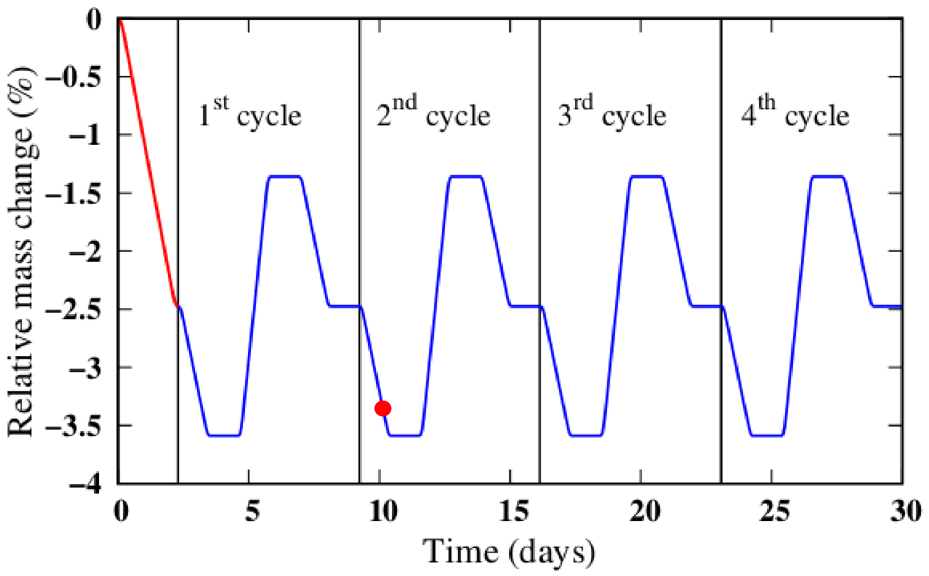
In the cavern

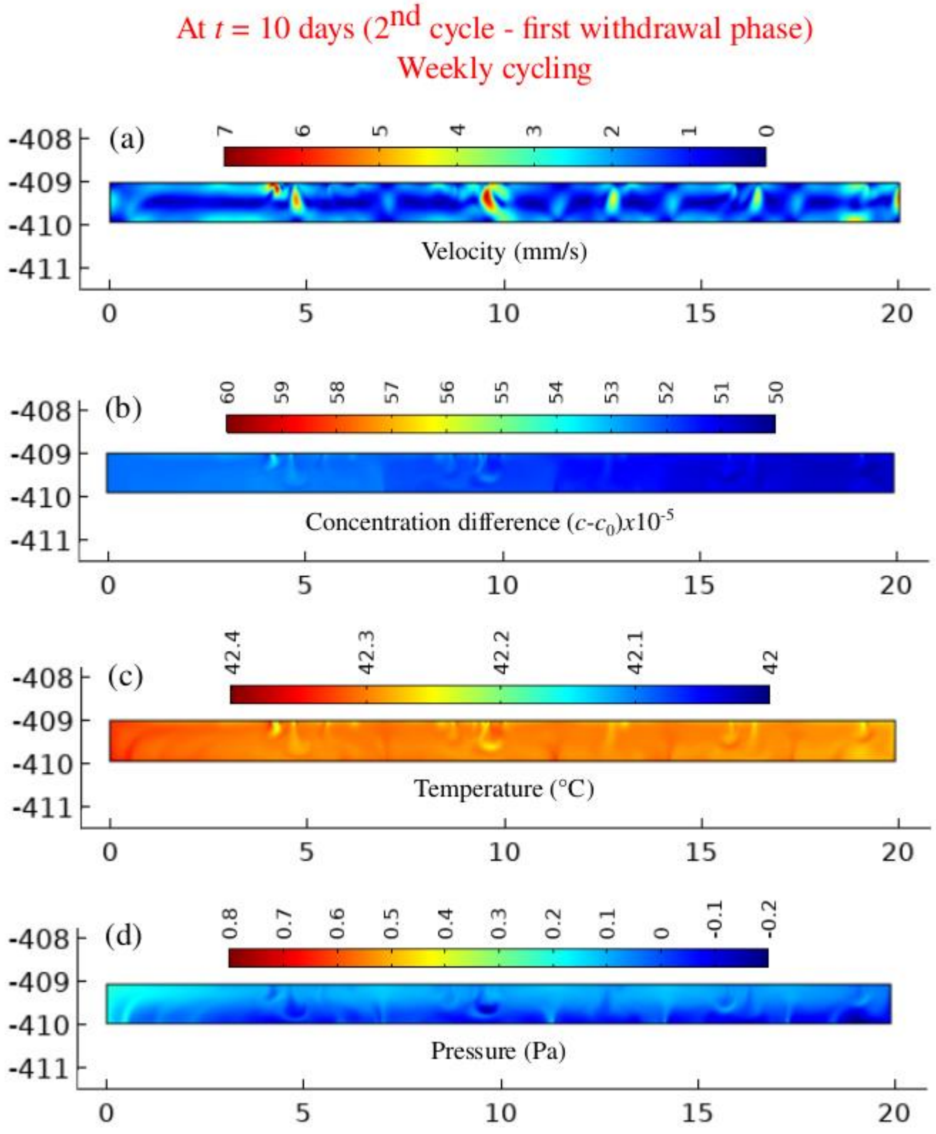
In the brine





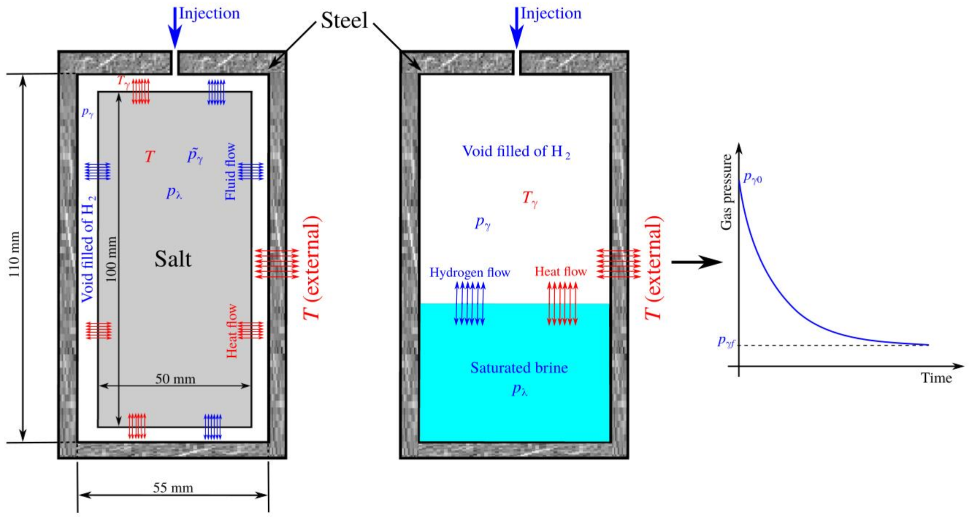
In the brine


1st cycle
2nd cycle
3rd cycle
4th cycle
Relative mass change (%)
Time (days)


At t = 10 days (2nd cycle - first withdrawal phase)
Weekly cycling
(a)
Velocity (mm/s)
(b)
Concentration difference (c-c0)x10-5
(c)
Temperature (°C)
(d)
Pressure (Pa)

CONCLUSION

- A non-dimensional model that couples the cavern thermodynamics with the gas dissolution mechanisms in brine during cycling
- This work helped better understand that:
    1. the quantity the dissolved gas is insignificant with regard to the initial stored mass (0.32%) or the cycled mass;
    2. however, the kinetics of dissolution must be quantified to broad other mass exchange phenomena (like permeation);
    3. and to keep good tracks of the cycled quantities of expensive gases like hydrogen.



(a) Two-phase flow parameters
(b) Kinetics of dissolution