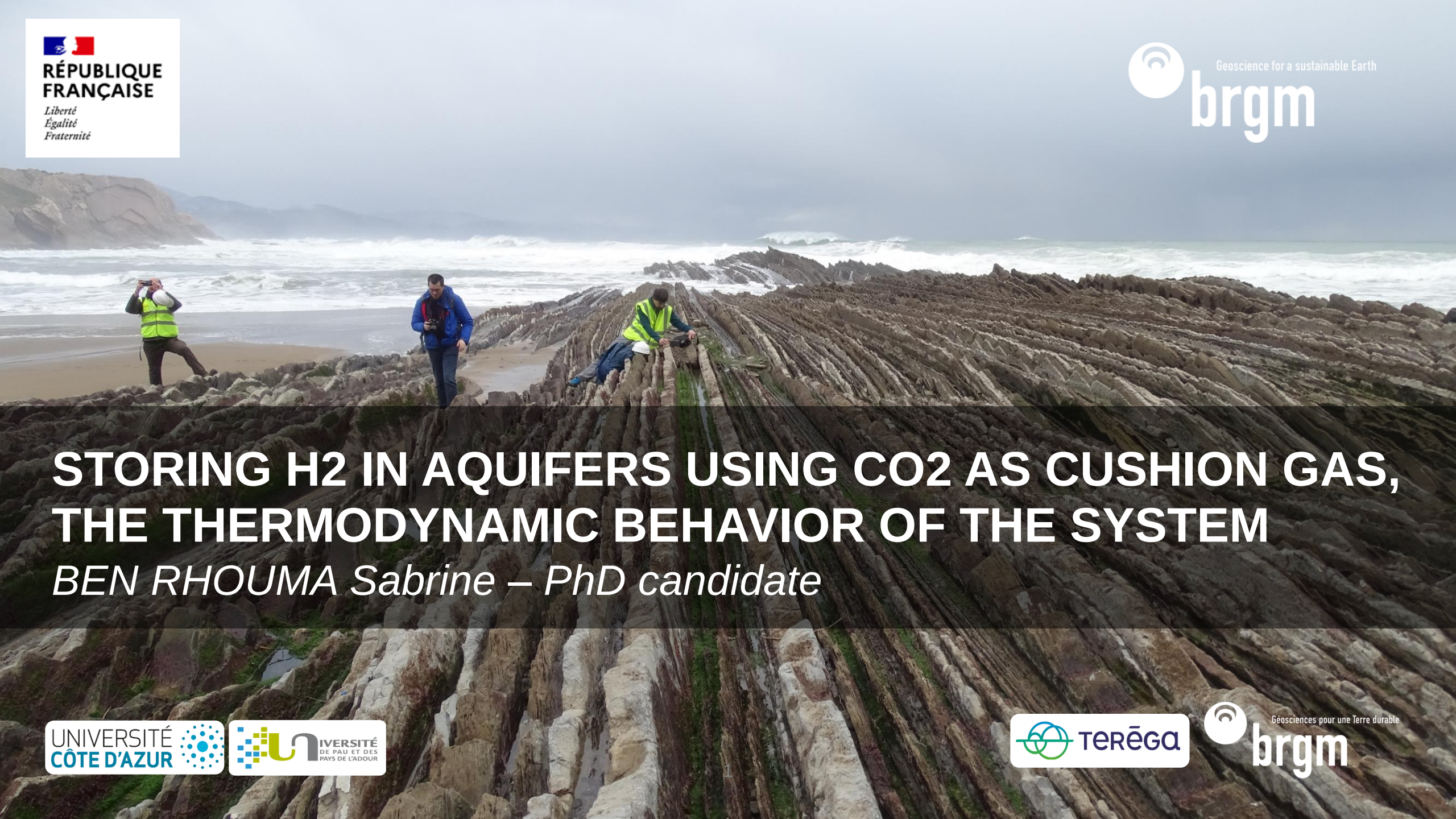
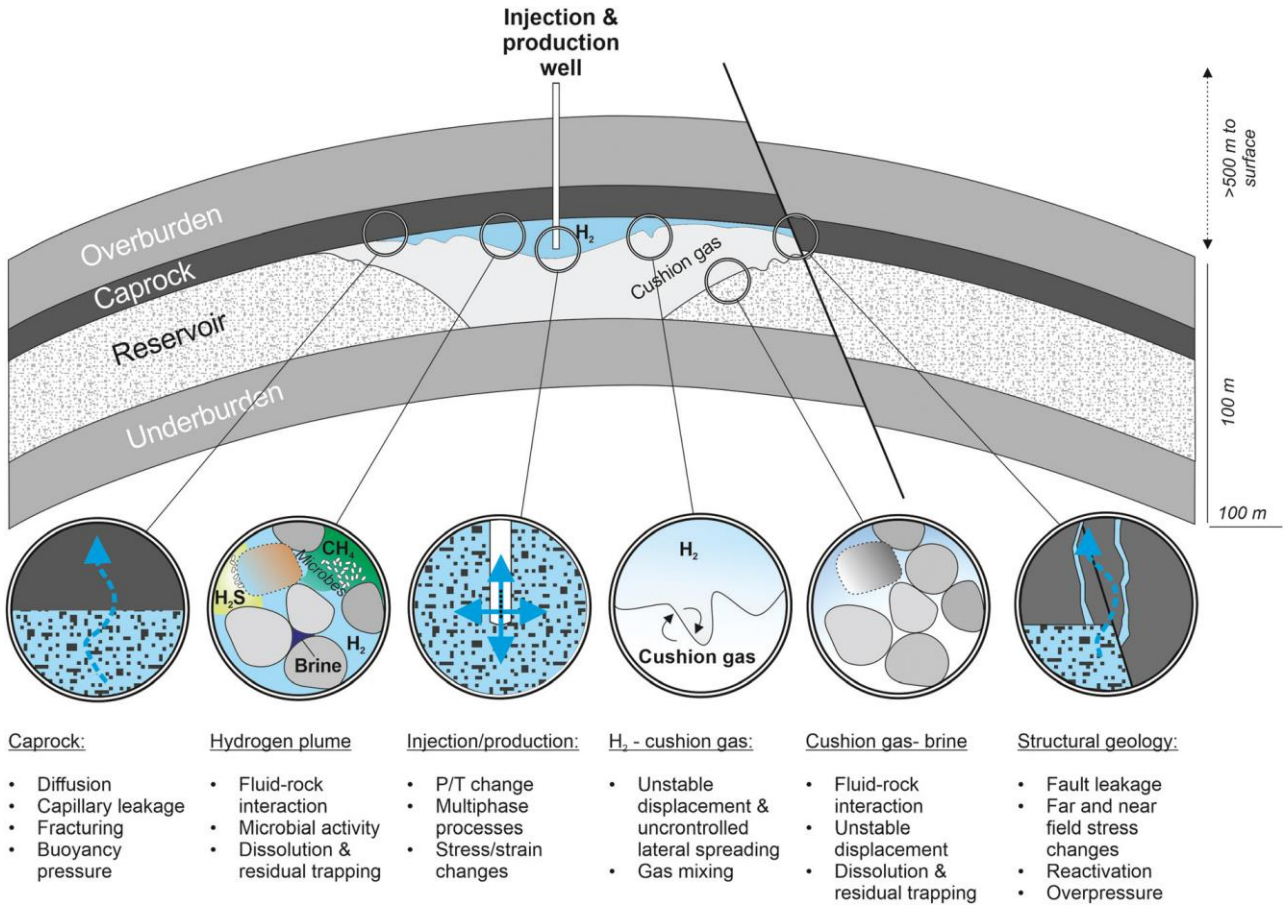


STORING H2 IN AQUIFERS USING CO2 AS CUSHION GAS, THE THERMODYNAMIC BEHAVIOR OF THE SYSTEM

BEN RHOUMA Sabrine – PhD candidate

Introduction

Storing H_2 in aquifers



Cushion gas represents 30-60% of total gas

- **Using H_2 increases** investment costs
- **Other cushion gases**
  - **would mix** with H_2 and increase operational costs
  - **would react** with H_2 assisted by microbial activity (or other catalysers)
- **CO_2 as cushion gas**
  - Environmental benefits
  - Decreases investment costs
  - Interesting physical properties around critical point

Streett et al., 1983 « Phase Equilibria in Hydrogen Binary Mixtures From 63 to 280 K and Pressures to 6000 Bars ».

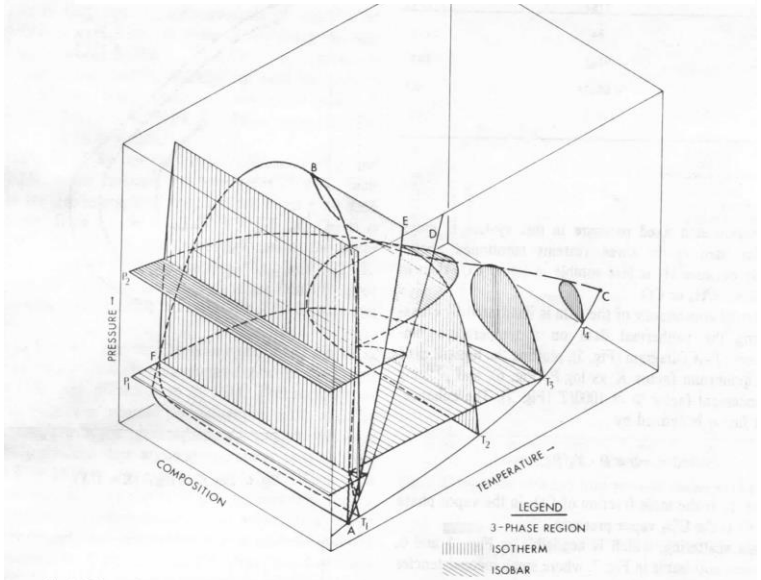
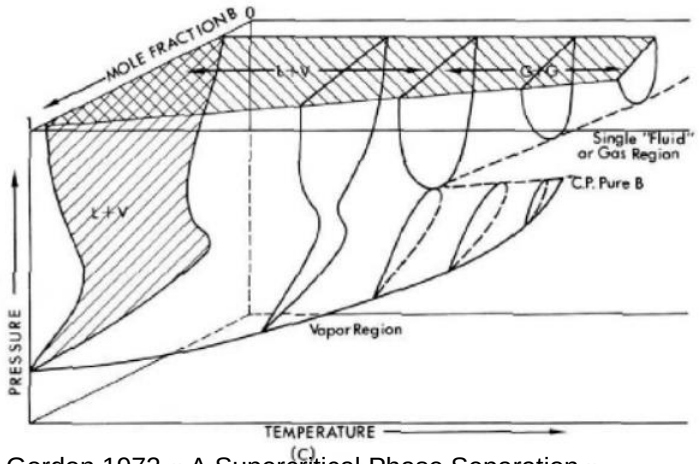


Fig. 4. Schematic three-dimensional draeing of $P-T-X$ diagram. The vertical planes T_1-T_4 are isotherms and the horizontal planes P_1 and P_2 are isobars. The shaded surface $AFBEA$ is the region of coexistence of solid, liquid and vapor phases (see text for discussion).



Gordon,1972 « A Supercritical Phase Separation ».

Introduction

CO_2 as cushion gas

What about H_2 - CO_2 mixing and reaction?

Mixing

- **thermodynamic behaviour** of the system H_2 - CO_2;
- Reservoir conditions and reservoir quality;
- Injection and withdraw rates

Reaction (not studied here but)

- Examples of methanation in situ involve other gases, not only pure CO_2
- Sabatier reaction occurs at high temperature (300°C to 400°C)
- Uncertainty of microbial activity kinetic

CO_2 - H_2 system

Type III Phase Diagram

Property	Hydrogen	CO2	CO2 critical (32°C at 73 bars)
Density (gaseous) at 0°C, 1 bar (kg/m3)	0.089	1.951	
Density at 25° C, 100 bar (kg/m3)	7.67	813.9	434.87
Density at 50° C, 100 bar (kg/m3)	7.1	384.4	
Boiling point (1bar)	-252.76°C	-78,6°C	
Viscosity at 25° C, 100 bar (µPa-s)	9.15	75.29	35.103
Viscosity at 50° C, 100 bar (µPa-s)	9.638	28.34	
Coefficient of compressibility at 25° C, 100 bar (Z)	1.06	0.2186	0.37149
Coefficient of compressibility at 50° C, 100 bar (Z)	1.056	0.4262	

Difference in physical parameters for H2 and CO2 at same P/T conditions
(data from Peace and NITS databases, 2021)

EoS capacities and limitations:

EoS \ H2 % mol	2	7,5	10
GERG 2008	4%	17,5%	14%
Peng Robinson	16%	10,5%	9%
SRK	16%	12%	10,5%

$CO_2 – H_2$ system

Phase diagram

Interesting properties of CO_2 around its critical point

Density

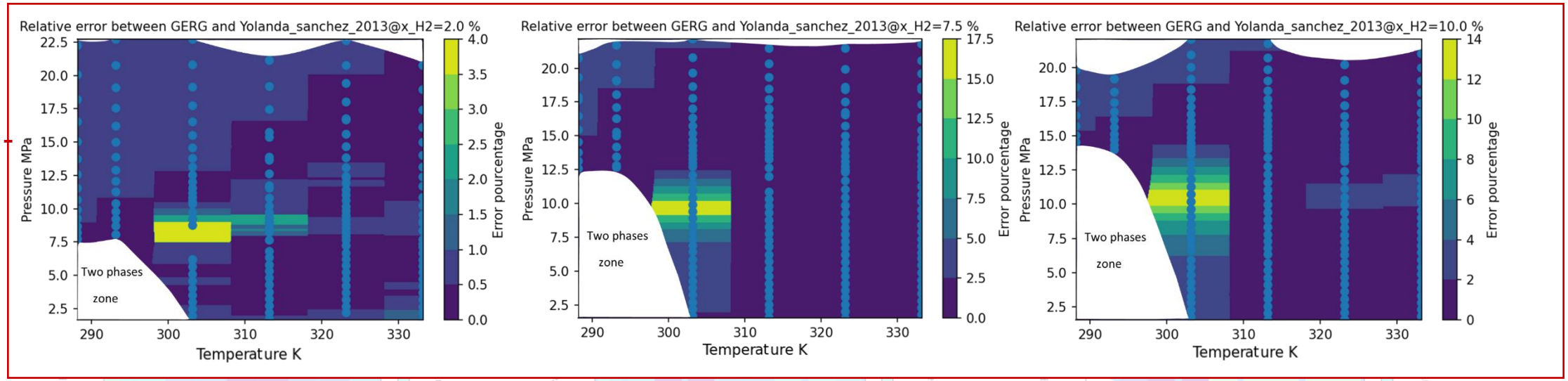
- Derived from Equation of states;
- High density contrast between CO_2 and H_2 at CO_2 critical point and around
- “Contaminants” sensitivity in pure CO_2 phase
  - a concentration of H_2 as low as 2% could lower the density by as much as 25% compared to pure CO_2 at “CCS conditions” (Sanchez-Vicente et al, 2013)

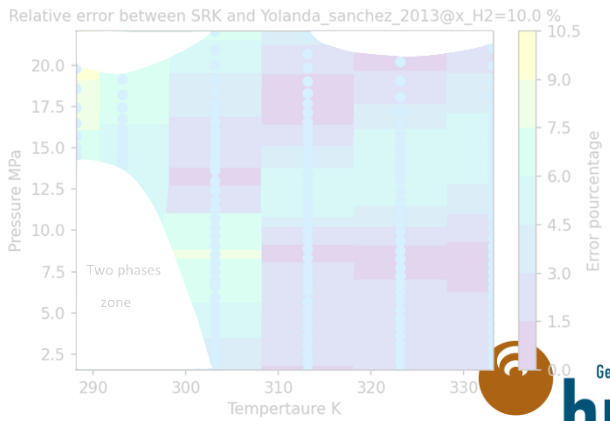
The maximum relative error between the experimental and calculated densities using different EoS

EoS capacities and limitations:

relative error between the experimental and calculated densities using different EoS

GERG 2008

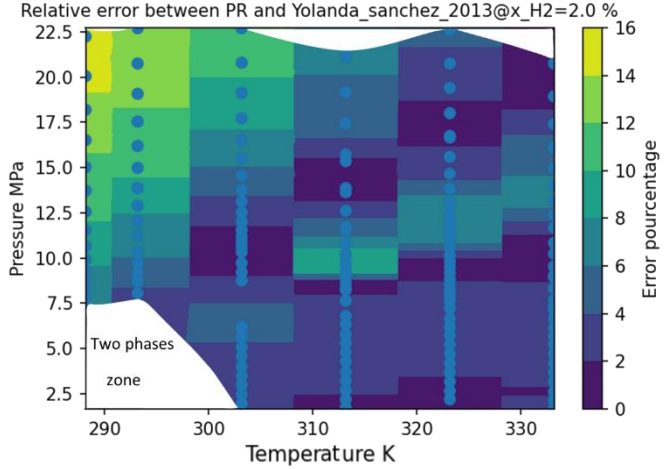


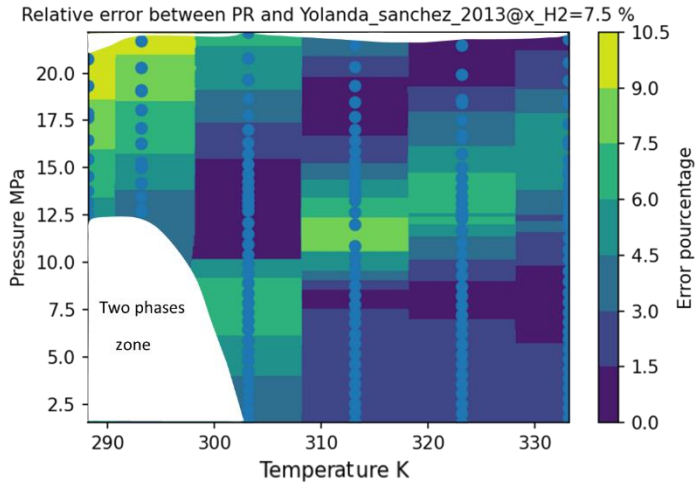


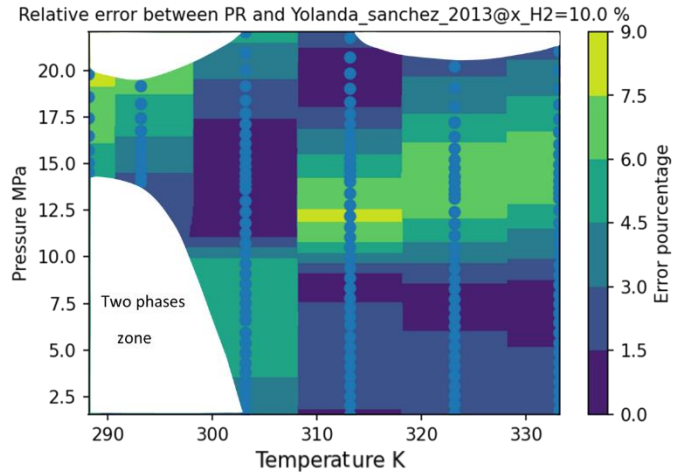
EoS capacities and limitations:

relative error between the experimental and calculated <u>densities</u> using different EoS

PR



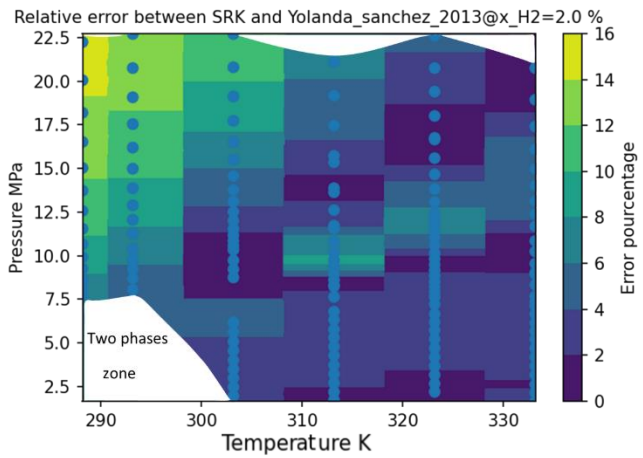


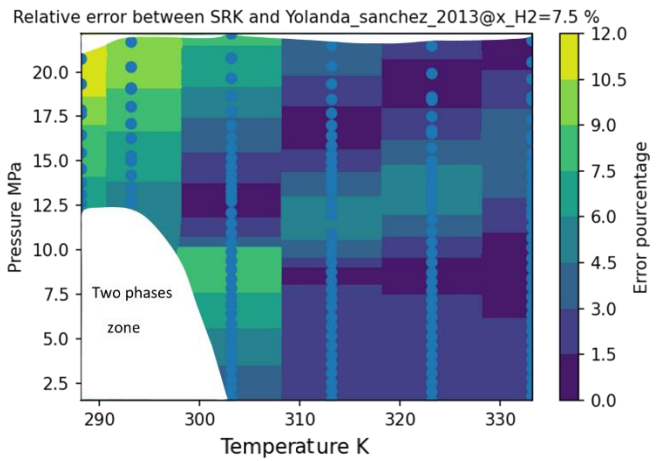


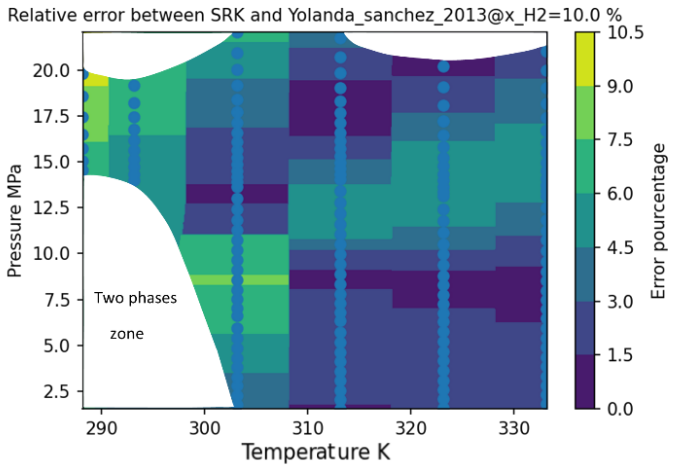
EoS capacities and limitations:

relative error between the experimental and calculated densities using different EoS

SRK



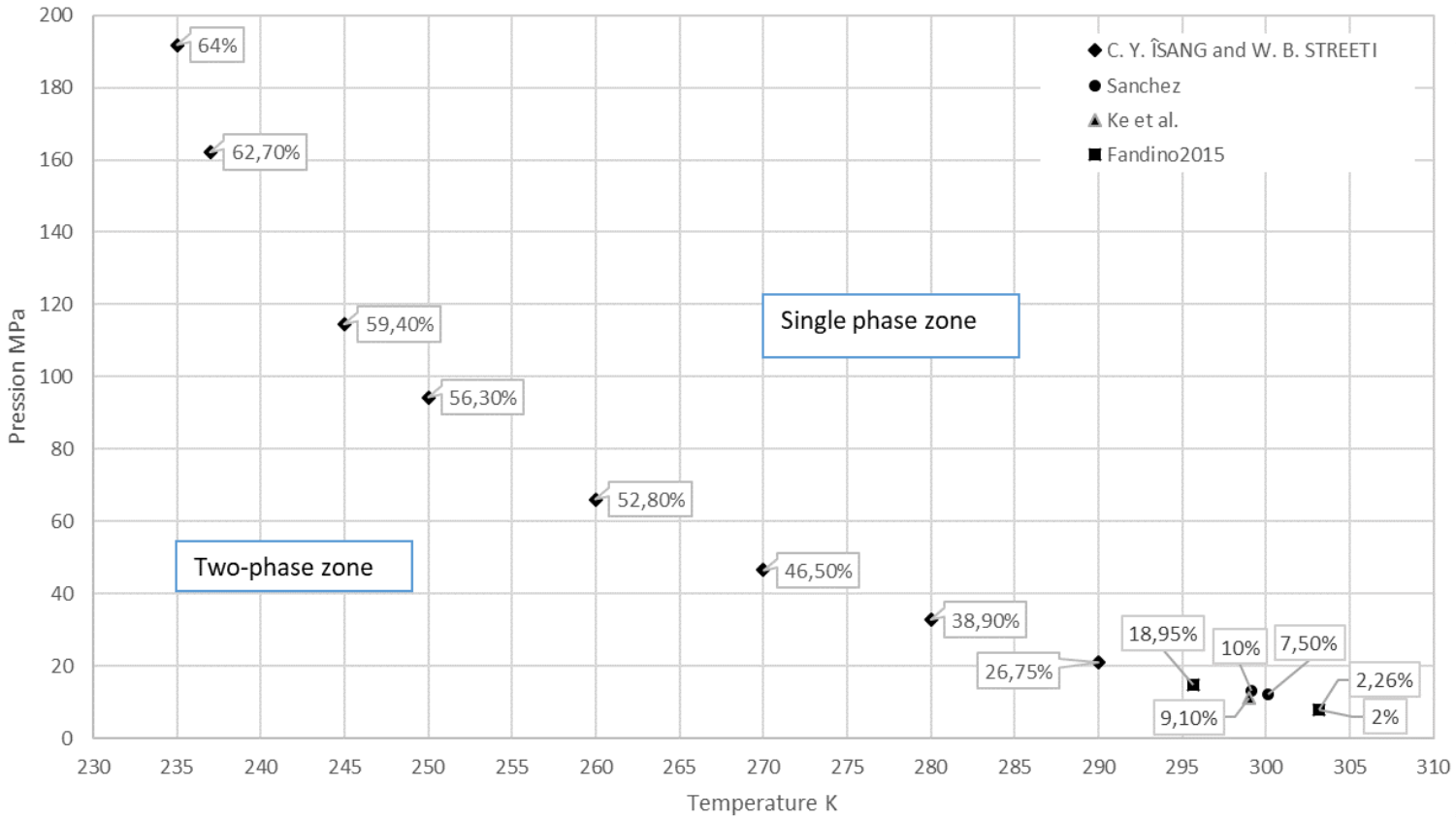


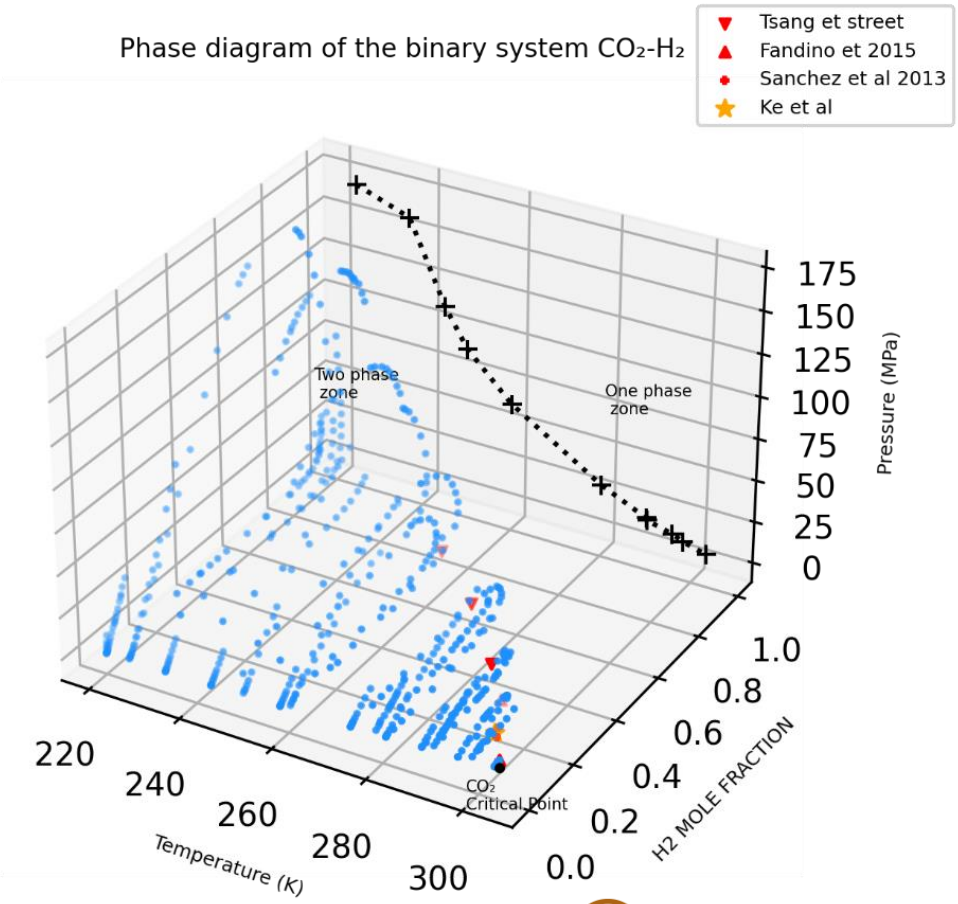


CO_2 – H_2 system

Phase diagram

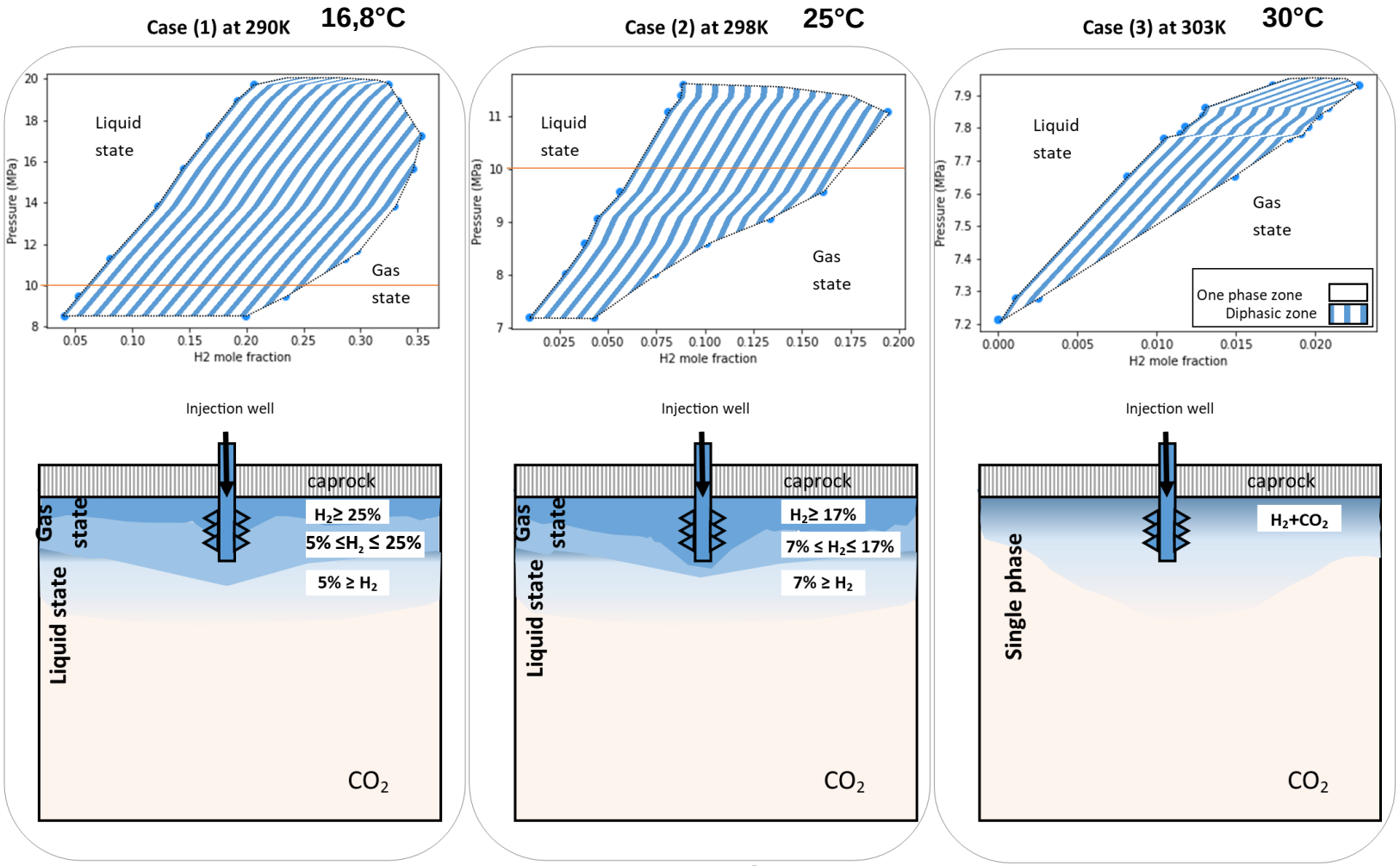
- thermodynamic behaviour of the system H_2 - CO_2





Phase diagram

- Conceptual model



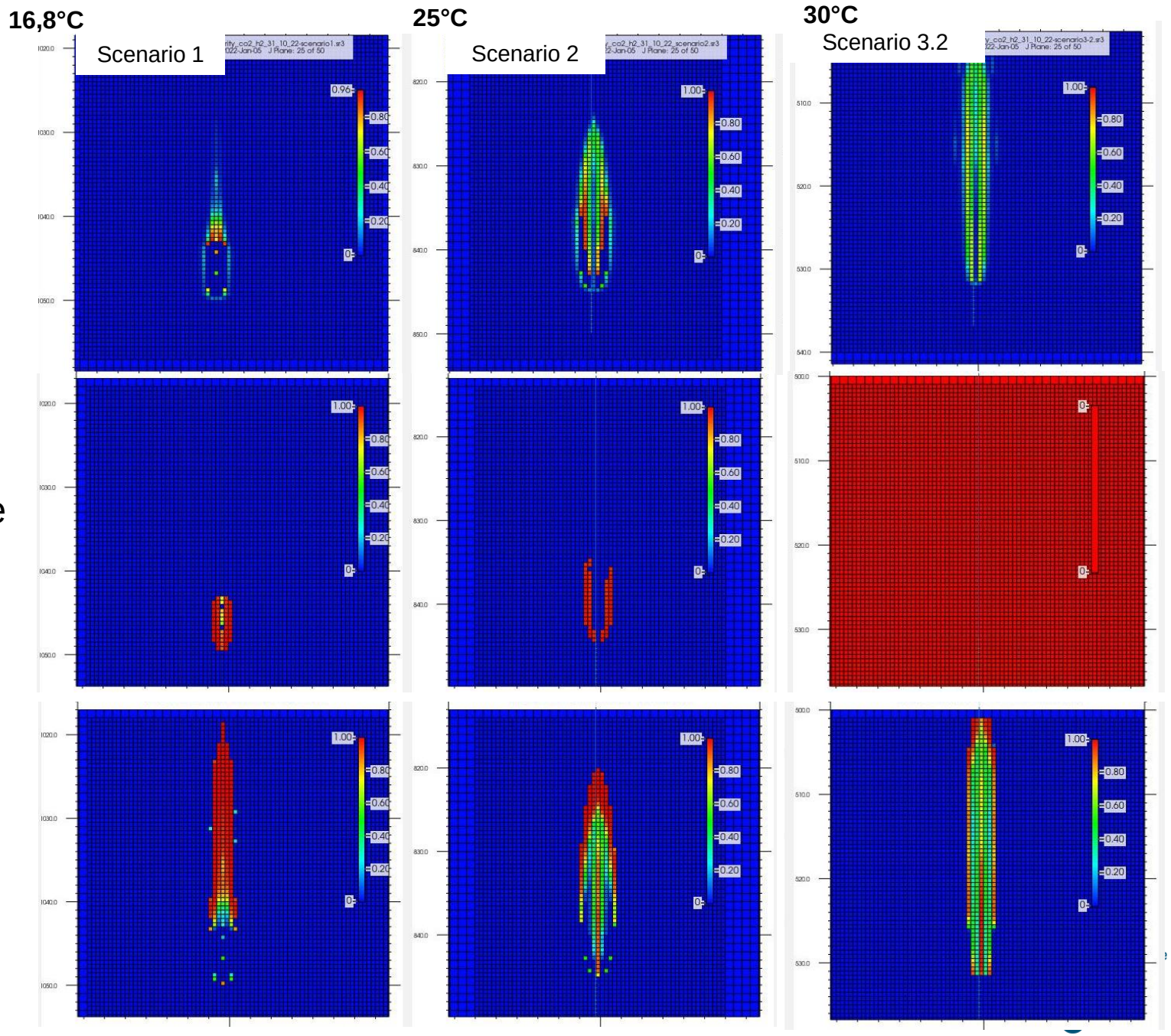
CO_2 – H_2 system

Concept simulation*

CO_2 gas mole fraction

CO_2 liquid mole fraction

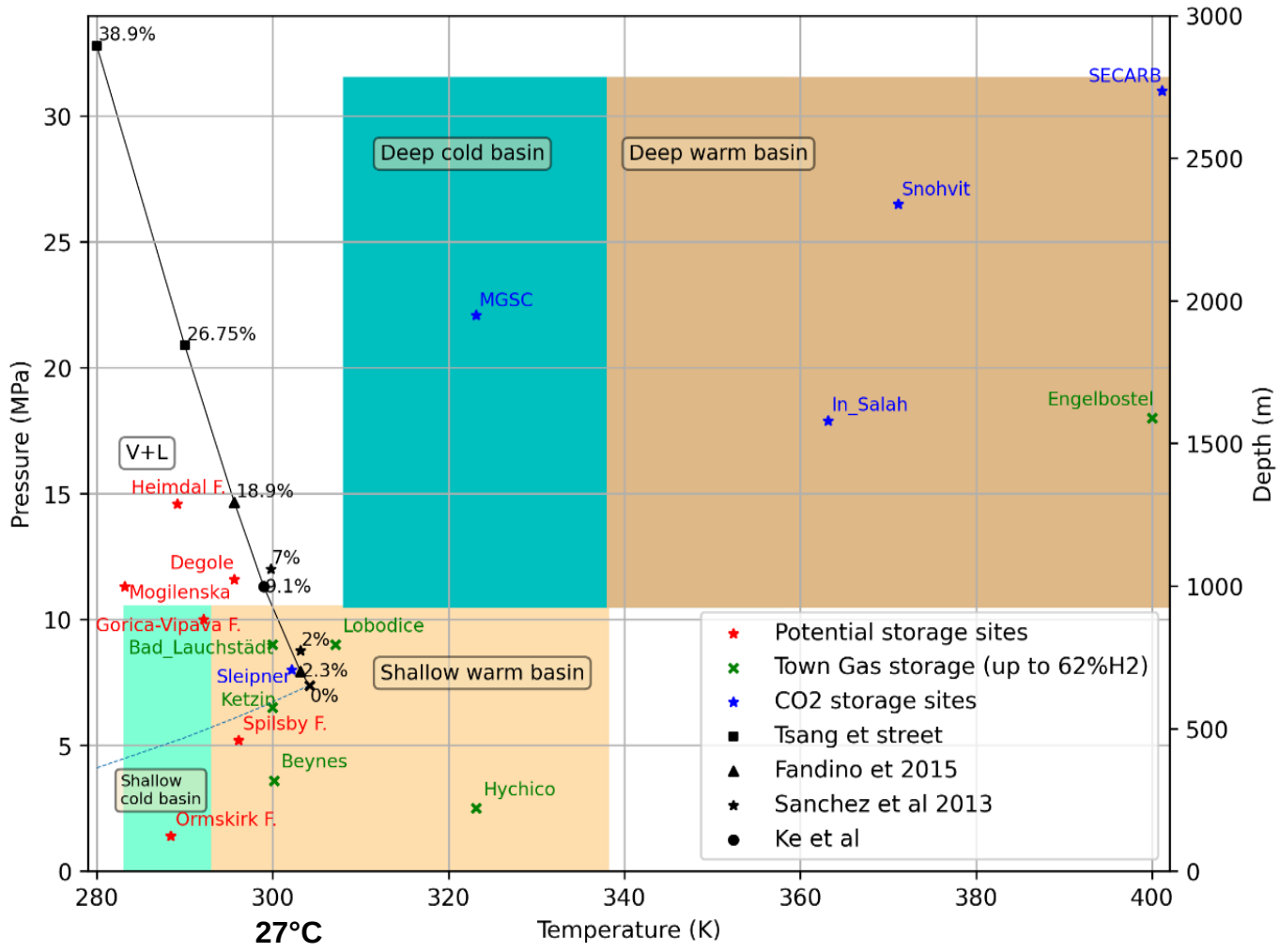
H_2 Gas mole fraction

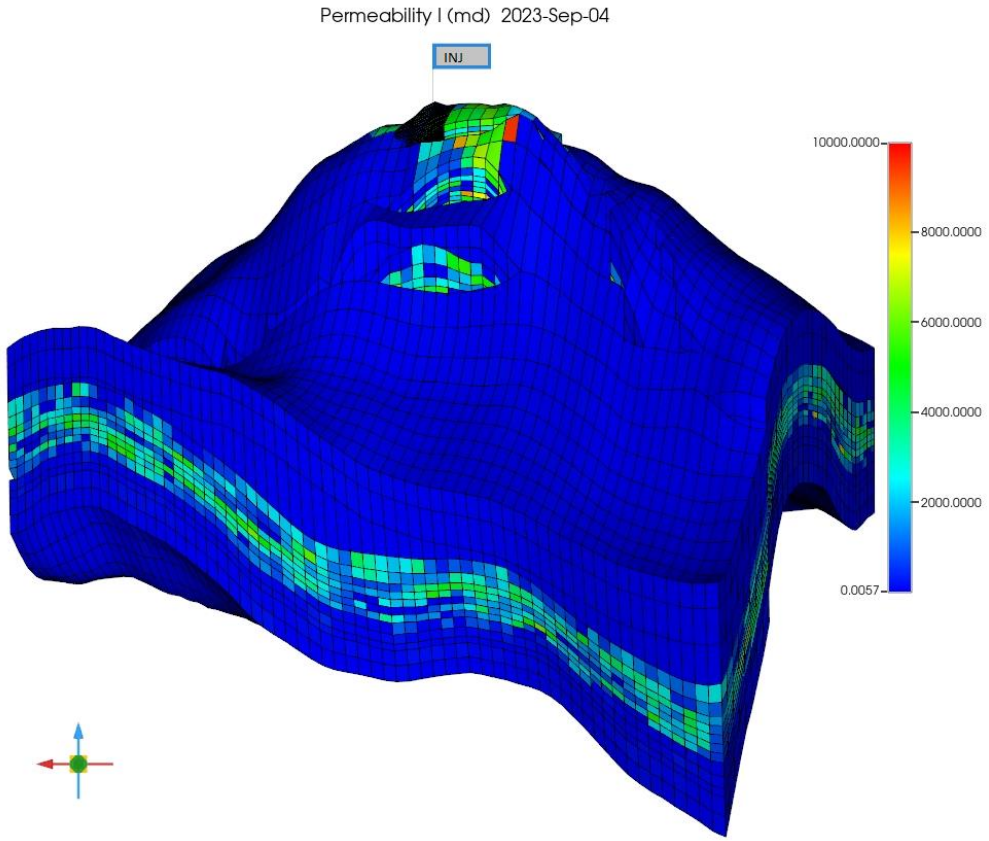


* CMG-GEM courtesy

Storage conditions CO_2 – H_2 system

- The investigation the P-T-x diagram of the system of interest concluded the possibility of 2 phases to exist.
- The examination of the different EoS is a valuable guidance towards a robust equation, in order to better describe the complex liquid –gas behavior.
- A multicomponent, multiphasic module





Conclusions

Feasibility of H_2 – CO_2 aquifer storage

- **Offshore reservoirs** are promising targets to enable the concept,
- **Two-phase zone** would serve as buffer zone limiting mixing
- Challenge to simulate realistic cases
  - **Numerical complexity**
  - **EoS uncertainties**

Ongoing Testing

Realistic case

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HEAD OFFICE – SCIENTIFIC AND TECHNICAL CENTRE
3, avenue Claude-Guillemin
BP 36009
45060 Orléans Cedex 2 - France
Tél.: +33 (0)2 38 64 34 34
Fax: +33 (0)2 38 64 35 18
www.brgm.eu

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Contact:
s.benrhouma@brgm.fr
BEN RHOUMA Sabrine