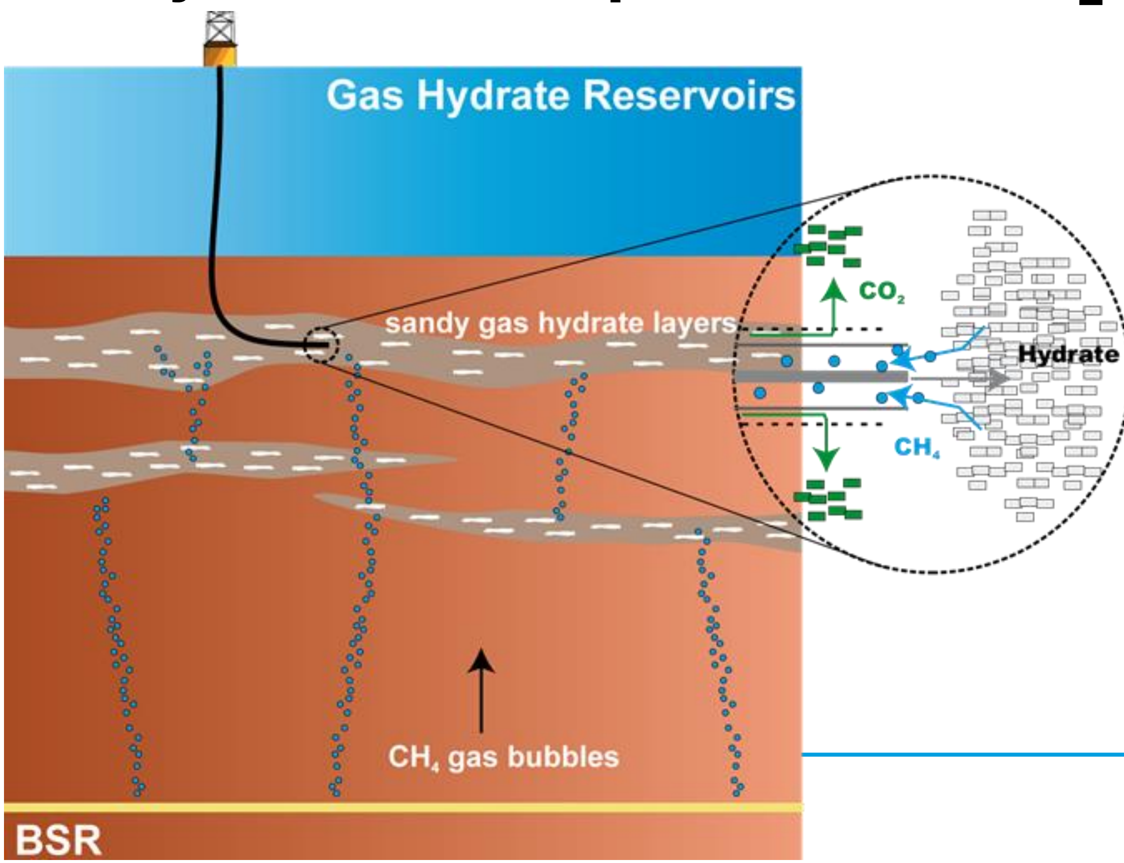
COMSOL CONFERENCE ROTTERDAM2013

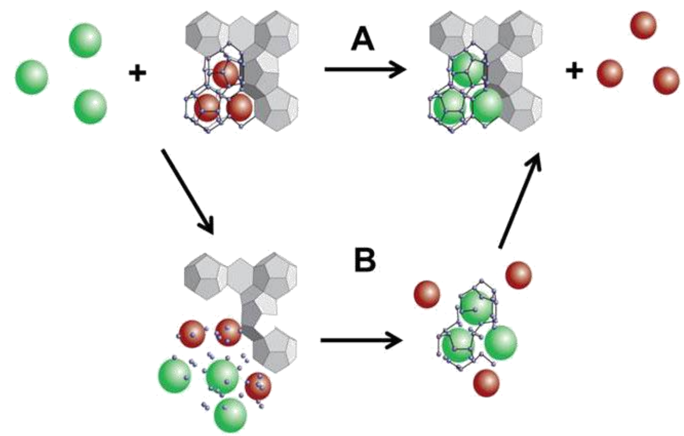
SUGAR

GEOMAR

A COMSOL Multiphysics®-based Model for Simulation of Methane-Hydrate Dissociation by Injection of Superheated CO_2

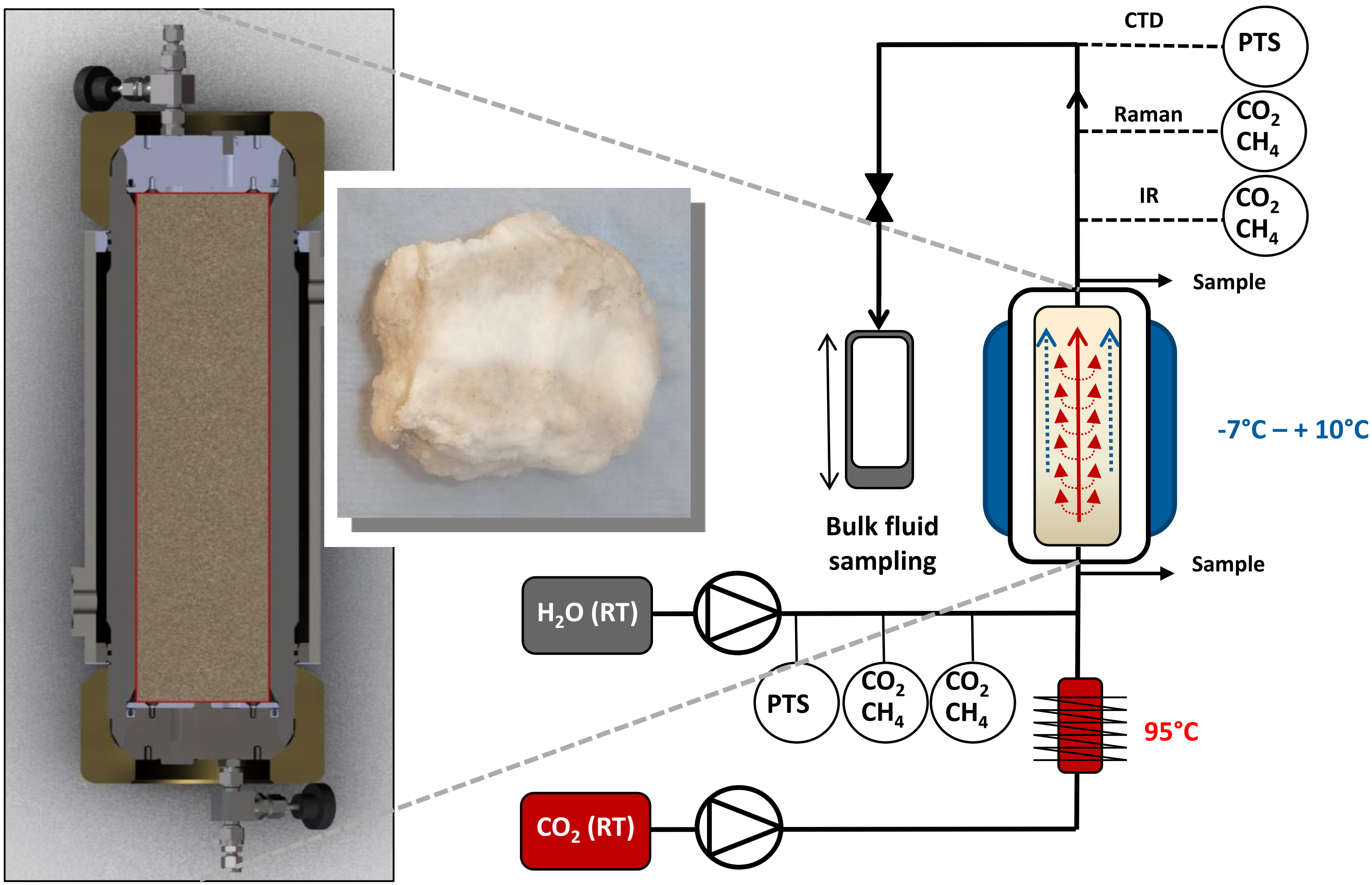


CH_4-CO_2-hydrate conversion

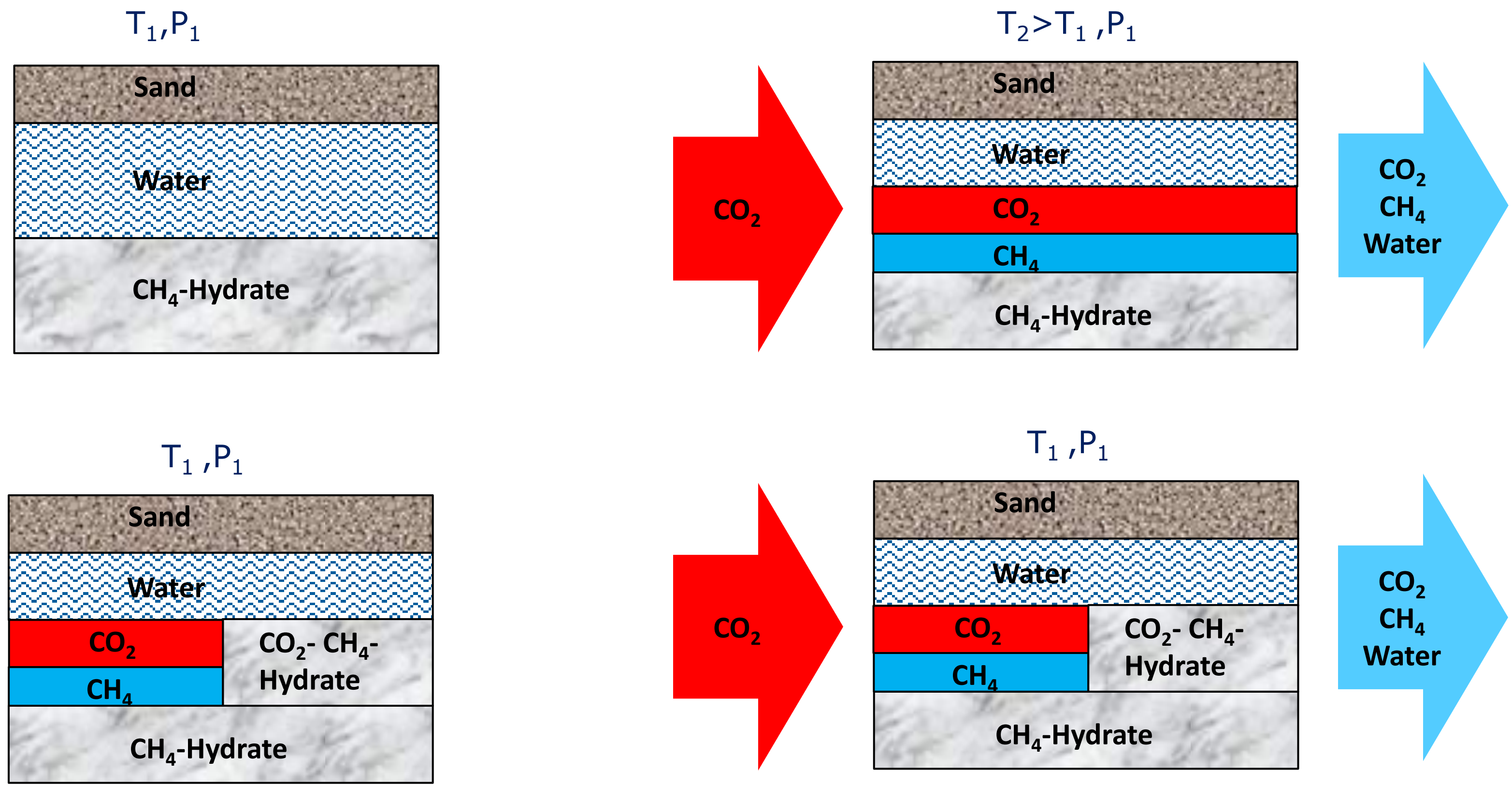


HELMHOLTZ ASSOCIATION

Experimental setup



Experiment steps



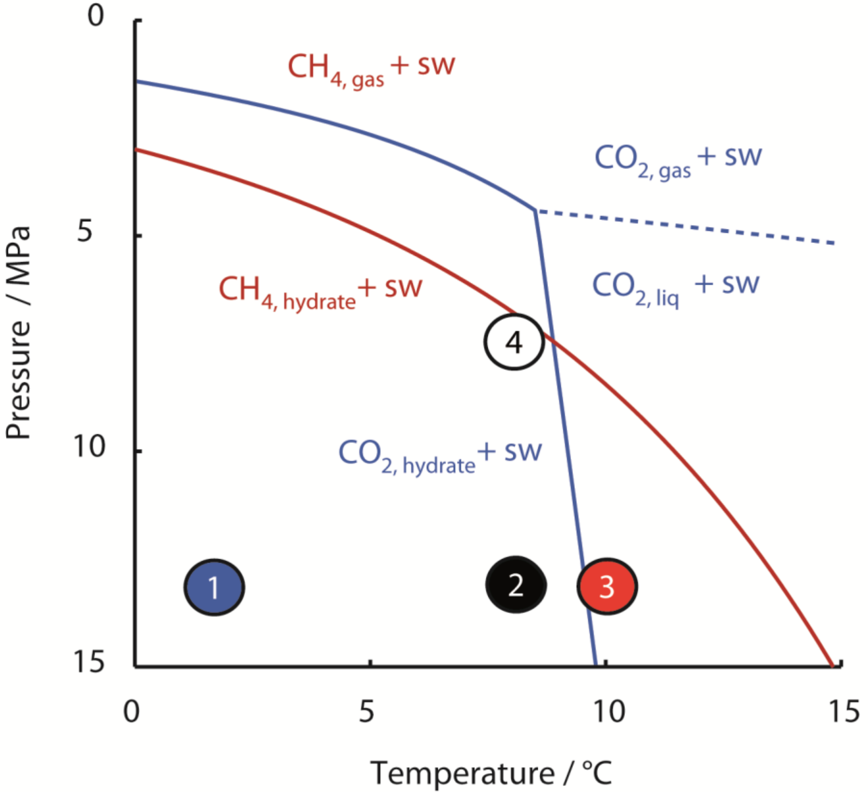
Experimental conditions

- **4 experiments at different p/T-conditions**

- 1) 2°C / 13 MPa
- 2) 8°C / 13 MPa
- 3) 10°C / 13 MPa
- 4) 8°C / 8 MPa

- **CO_2 injection**

- 95°C
- 2-5 ml/min



Reactions of interest

Under stability conditions:

CH_4-Hydrate ←→ CH_4(aqueous) + H_2O

CO_2(aqueous) + H_2O ←→ CO_2-Hydrate

CO_2(aqueous) ←→CO_2(liquid)

CH_4(aqueous) ←→CH_4(gas)

At dissociating conditions:

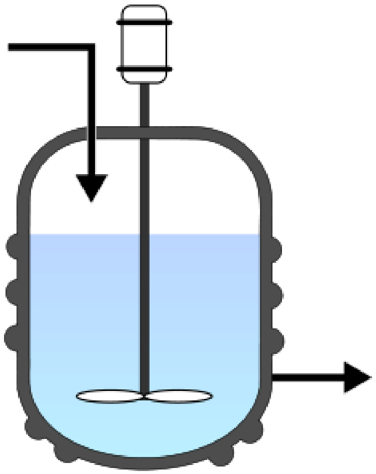
CH_4-Hydrate → CH_4(gas) + H_2O

CO_2-Hydrate →CO_2(liquid) + H_2O

- In CSTR model, mass and energy balance are solved explicitly and coupled to the reactivity in the system.

1. Bulk model approach

Using CSTR (continuous stirred tank reactor) and Batch



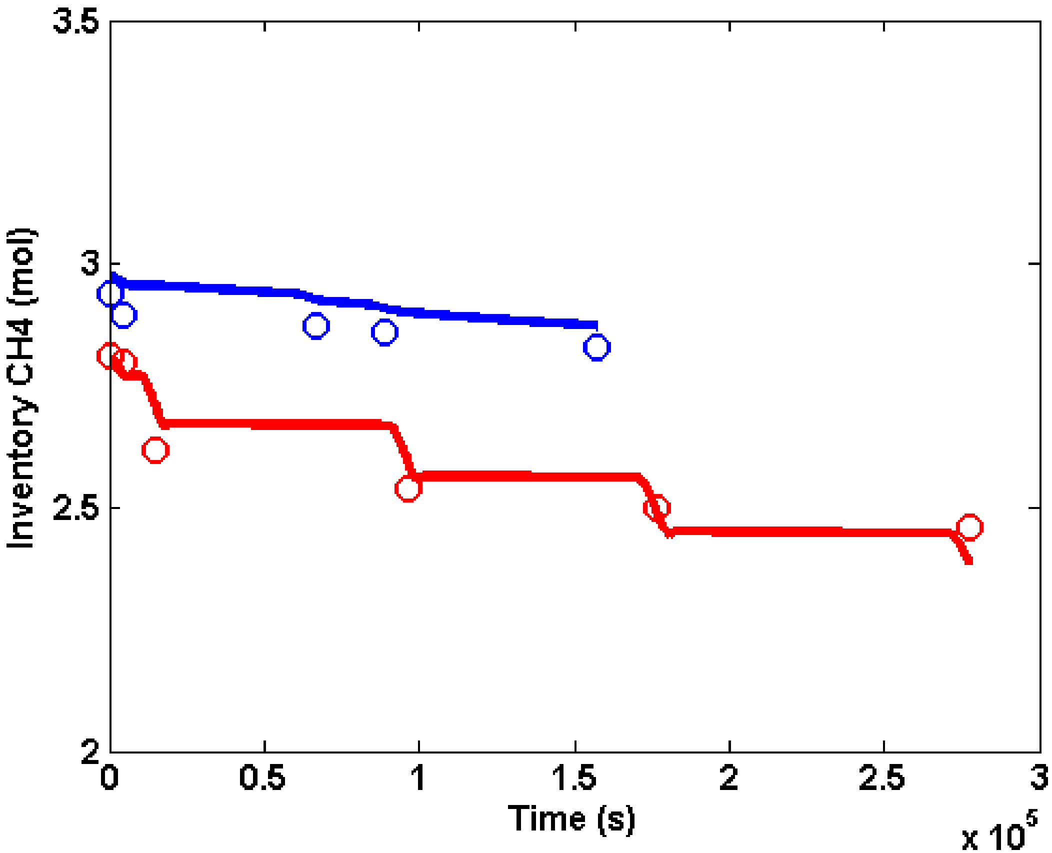
- Assuming the reactor as a non-isothermal CSTR
- Assuming the effects caused by transport limitations are negligible or included into the estimated effective rate parameters
- All properties (T, P, concentrations) are averaged over the reactor and therefore have one value.

CSTR modeling Pros and cons

- **Pros:**
- Fast, effective and computationally cheap
- Good approximations of dynamics at small-scales
- quick and easy for sensitivity analysis
- Better numerical convergence on higher non-linearities raised by complicated definitions of reaction rates – multiple reactions

- **Cons:**
- There is one averaged value for quantities like pressure, temperature and chemical concentrations
- CSTR can not address spatial properties and thus is not precise enough for reservoir modeling
- Medium geometry, inlet and outlet positions, shape of reservoir and etc. don’t influence the outcomes.
- Transport limitation effects are neglected.

CSTR Model preliminary results



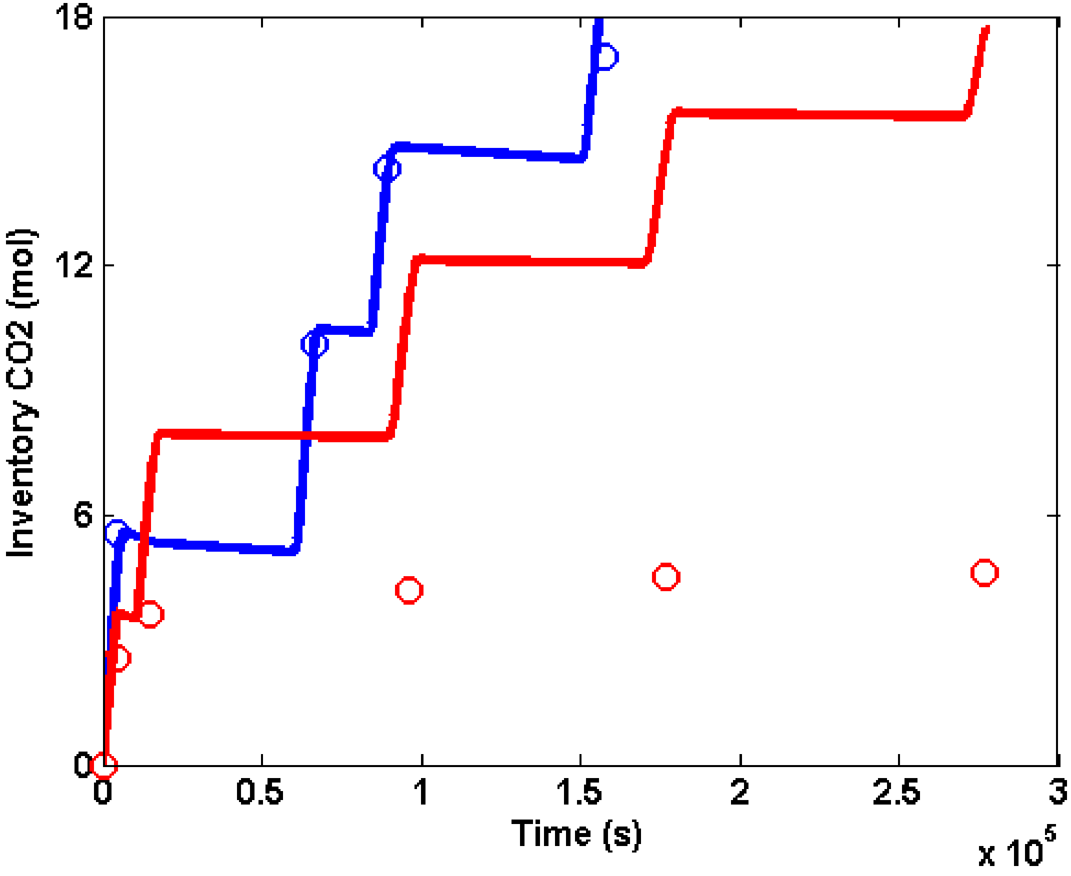
- Total CH4 in the system for experiment 1 and experiment 3.

- 1) 2°C / 13 Mpa
- 3) 10°C / 13 MPa

- **CO_2 injection**

- 95°C
- 2-5 ml/min

CSTR Model preliminary results



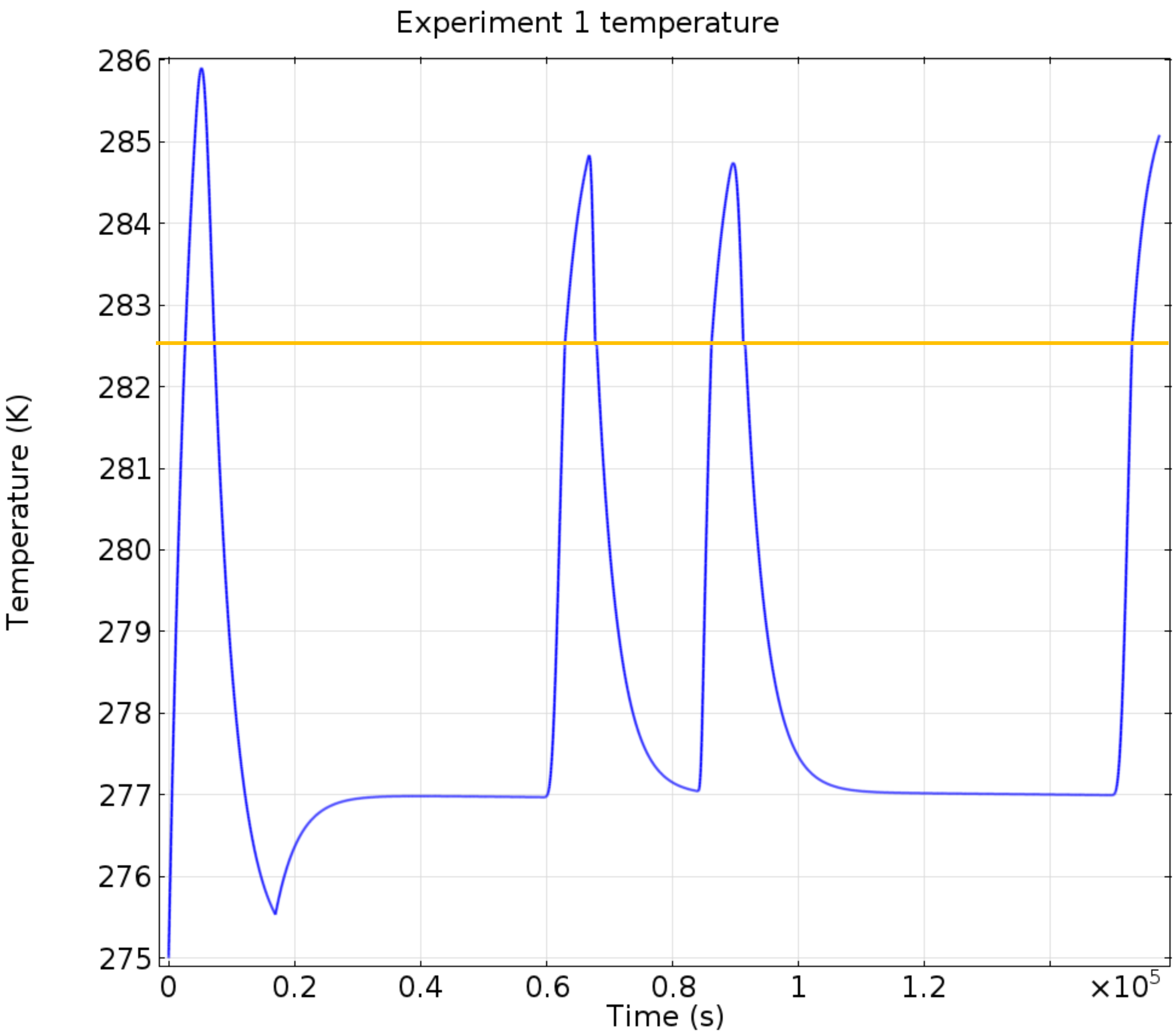
- Total CO2 in the system for experiment 1 and experiment 3.

- 1) 2°C / 13 Mpa
- 3) 10°C / 13 MPa

- **CO_2 injection**

- 95°C
- 2-5 ml/min

CSTR results for experiment 1

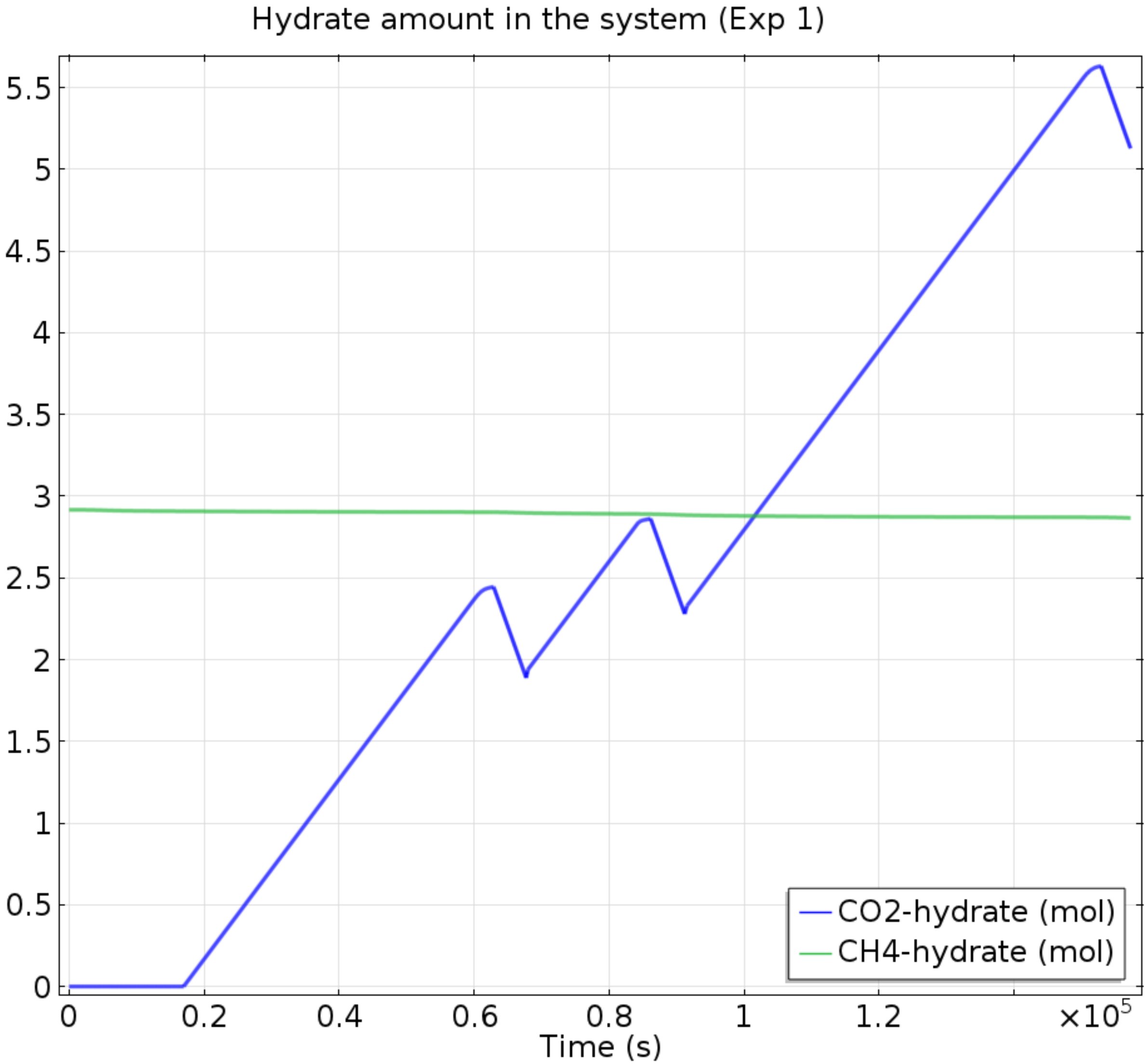


CH4 stability temperature= 287 K

CO2 stability temperature= 282.5 K

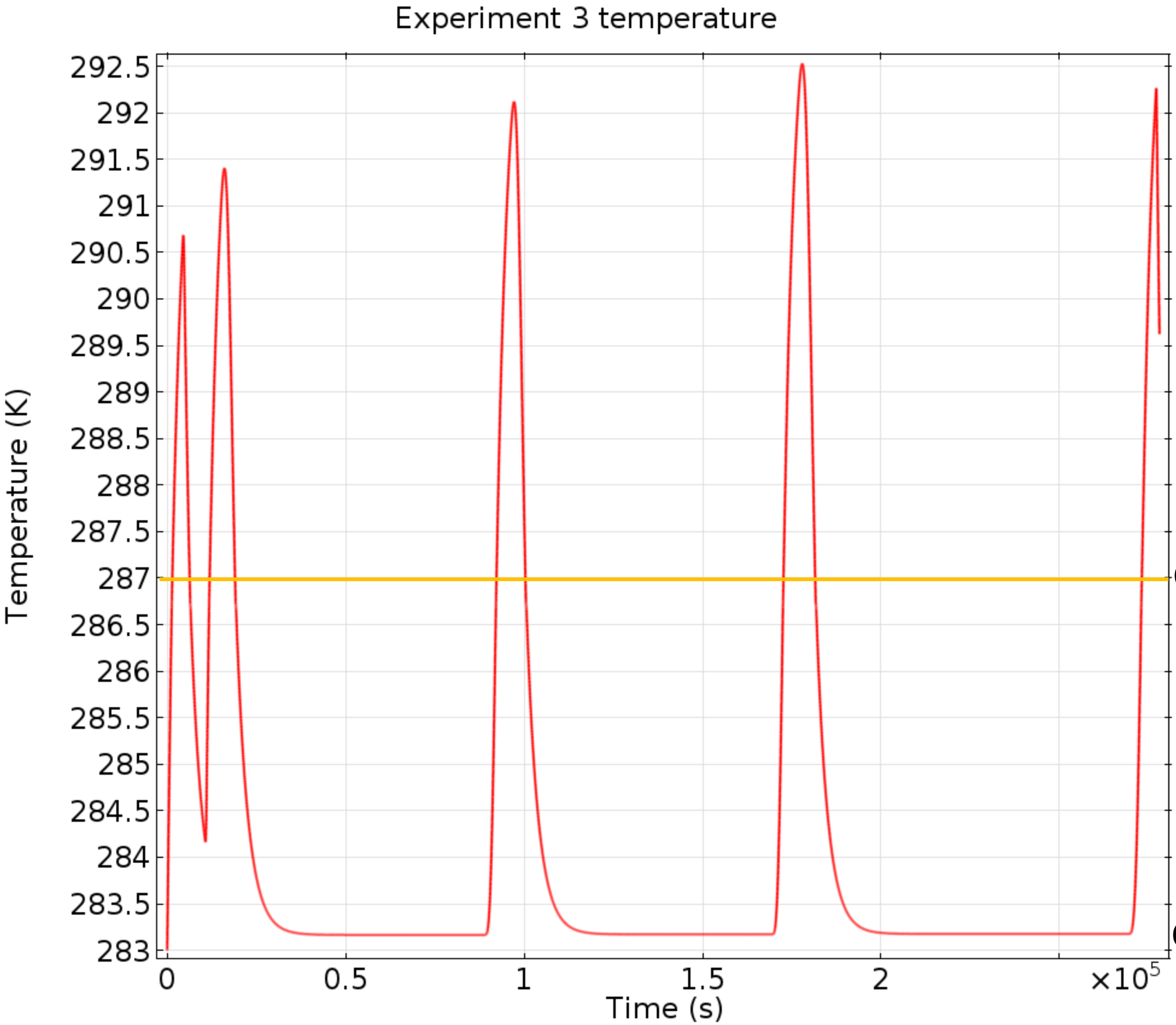
- Exp (1) 2°C / 13 Mpa
- **CO_2 injection**
- 95°C
- 2-5 ml/min

CSTR results for experiment 1



- Exp (1) 2°C / 13 Mpa
- **CO_2 injection**
- 95°C
- 2-5 ml/min

CSTR results for experiment 3

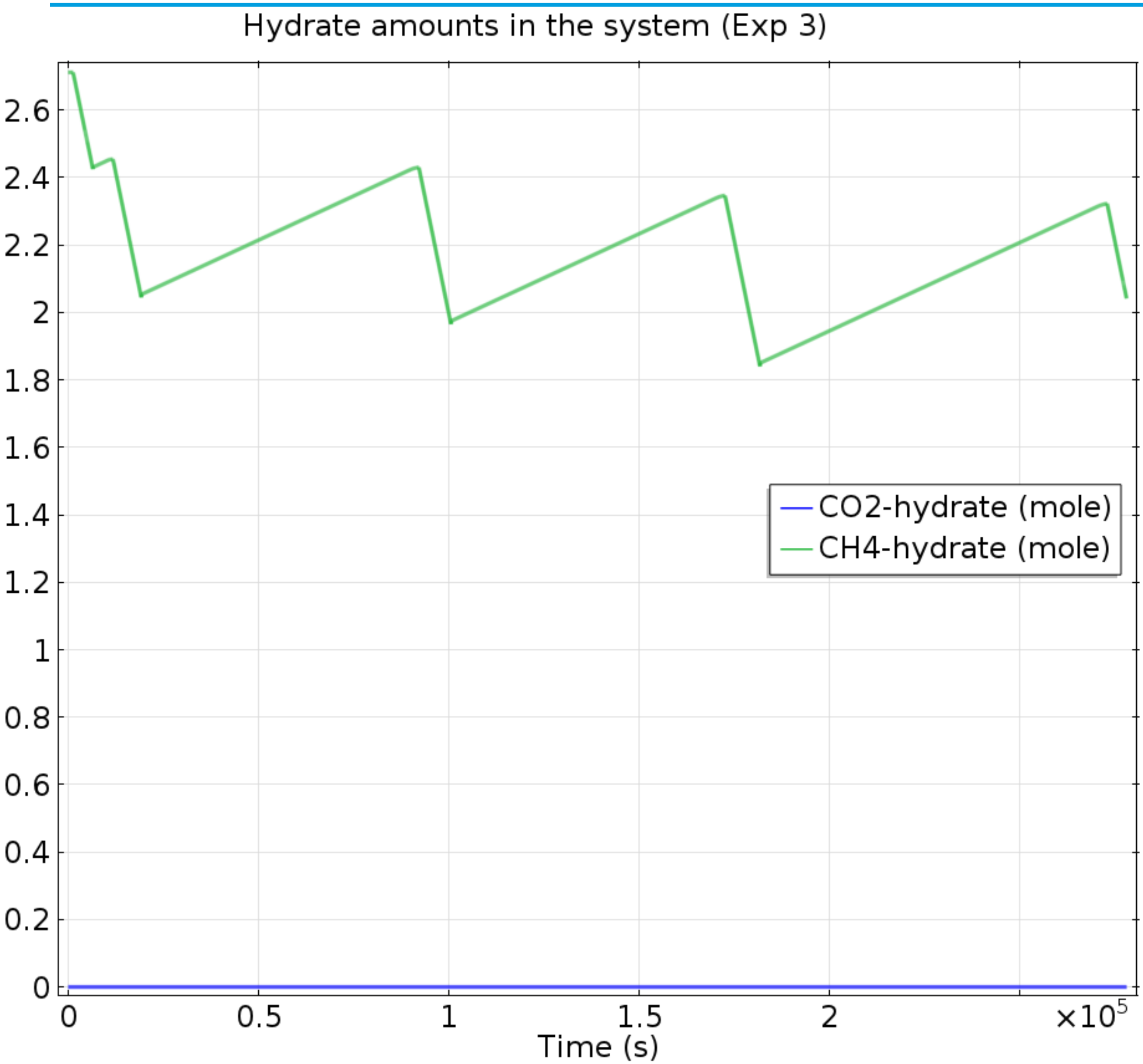


- Exp (3) 10°C / 13 MPa
- **CO_2 injection**
- 95°C
- 2-5 ml/min

CH4 stability temperature= 287 K

CO2 stability temperature= 282.5 K

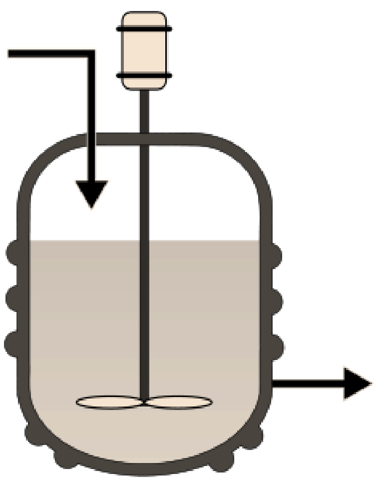
CSTR results for experiment 3



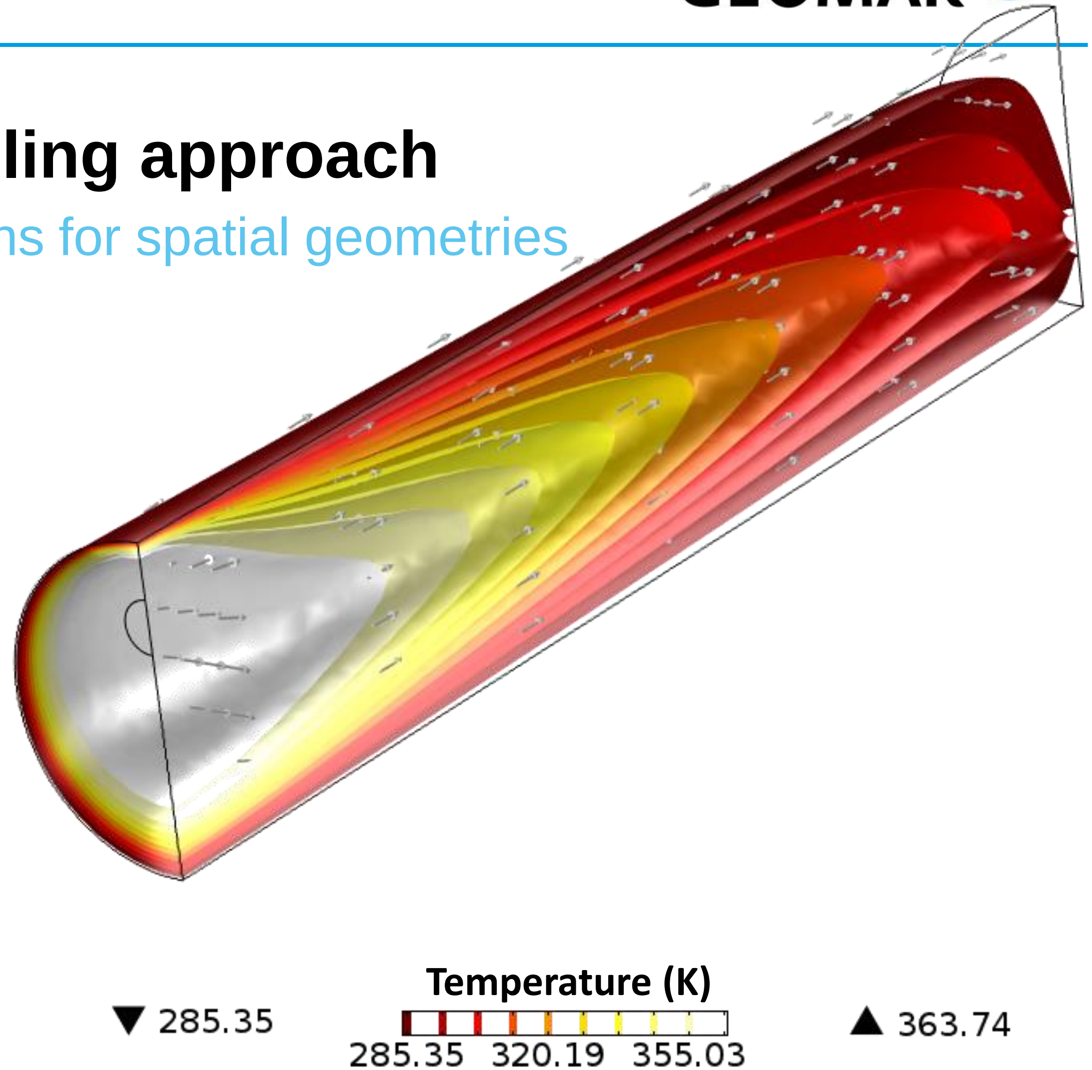
- Exp (3) 10°C / 13 MPa
- **CO_2 injection**
- 95°C
- 2-5 ml/min

2. Reservoir modeling approach

Solving the flow equations for spatial geometries



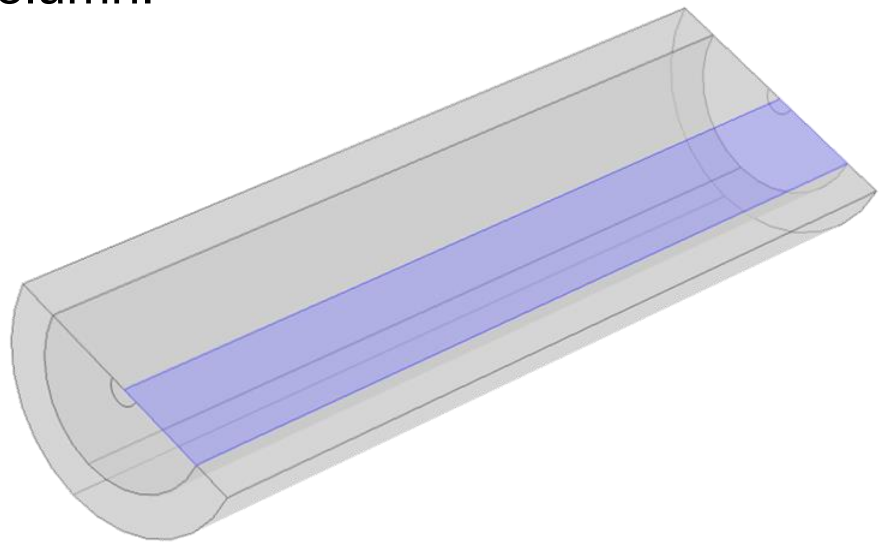
Average Temperature= 330 (K)



Two-phase fluid flow transport

- In order to include the spatial movement of the components in the model, development of a two-phase platform has been started.

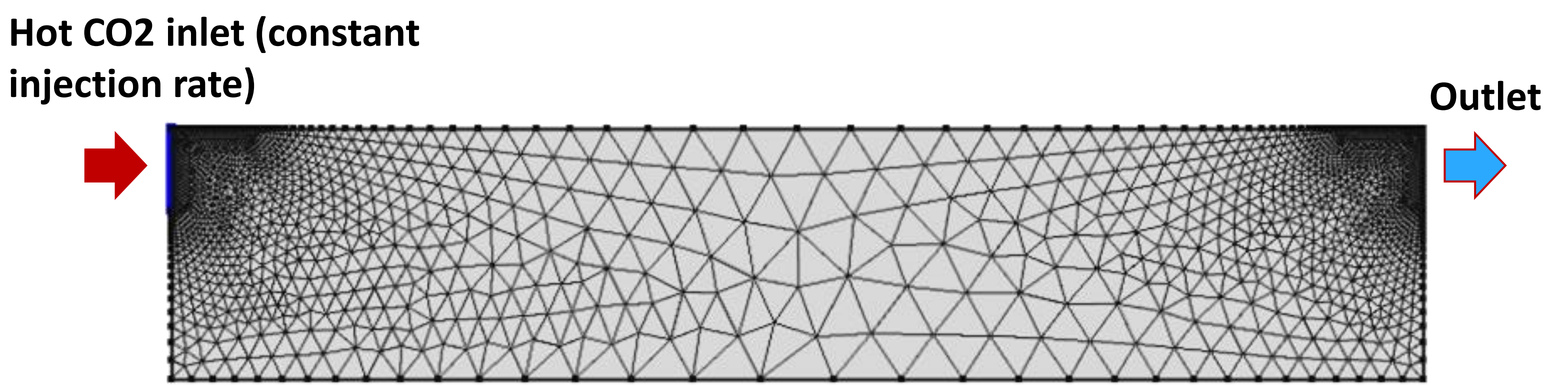
- In following a non-wet phase pushes the wetting phase out of an experimental column.



Two-phase fluid flow

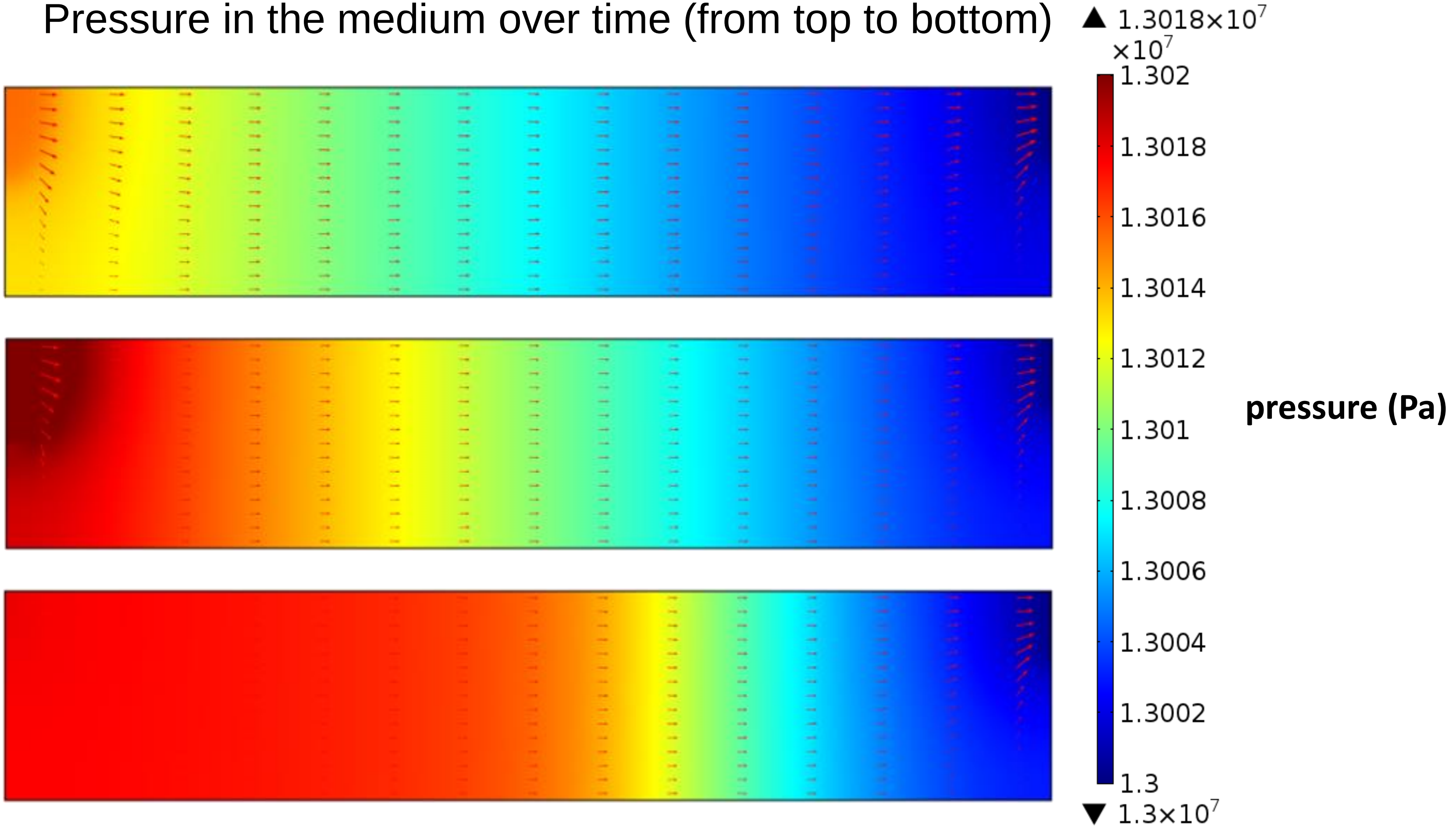
Medium and meshing

- At inlet non-wet phase (CO_2) enters the medium and wetting-phase (Water) depletes from outlet.



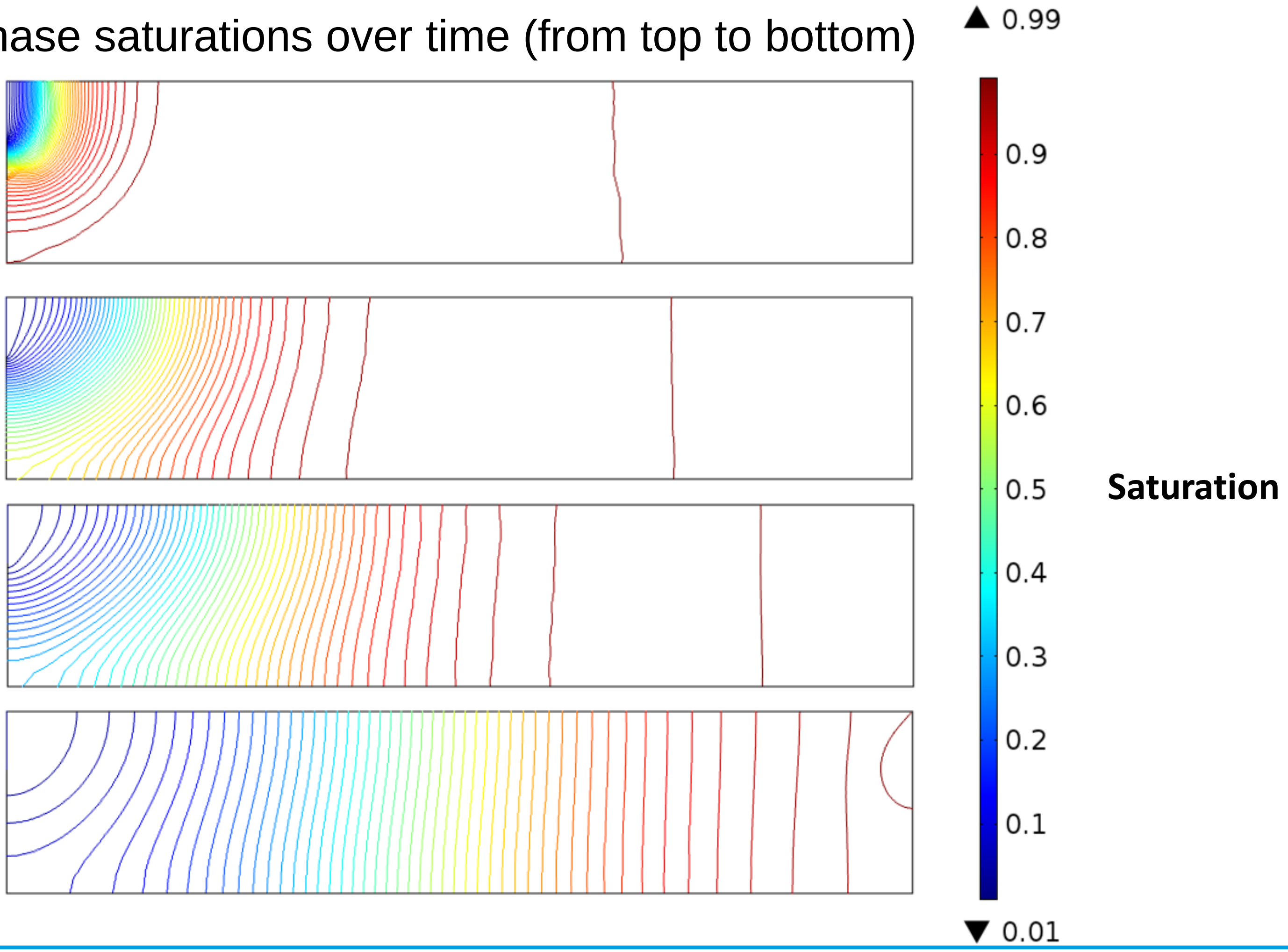
2-phase Model preliminary results

- Pressure in the medium over time (from top to bottom)



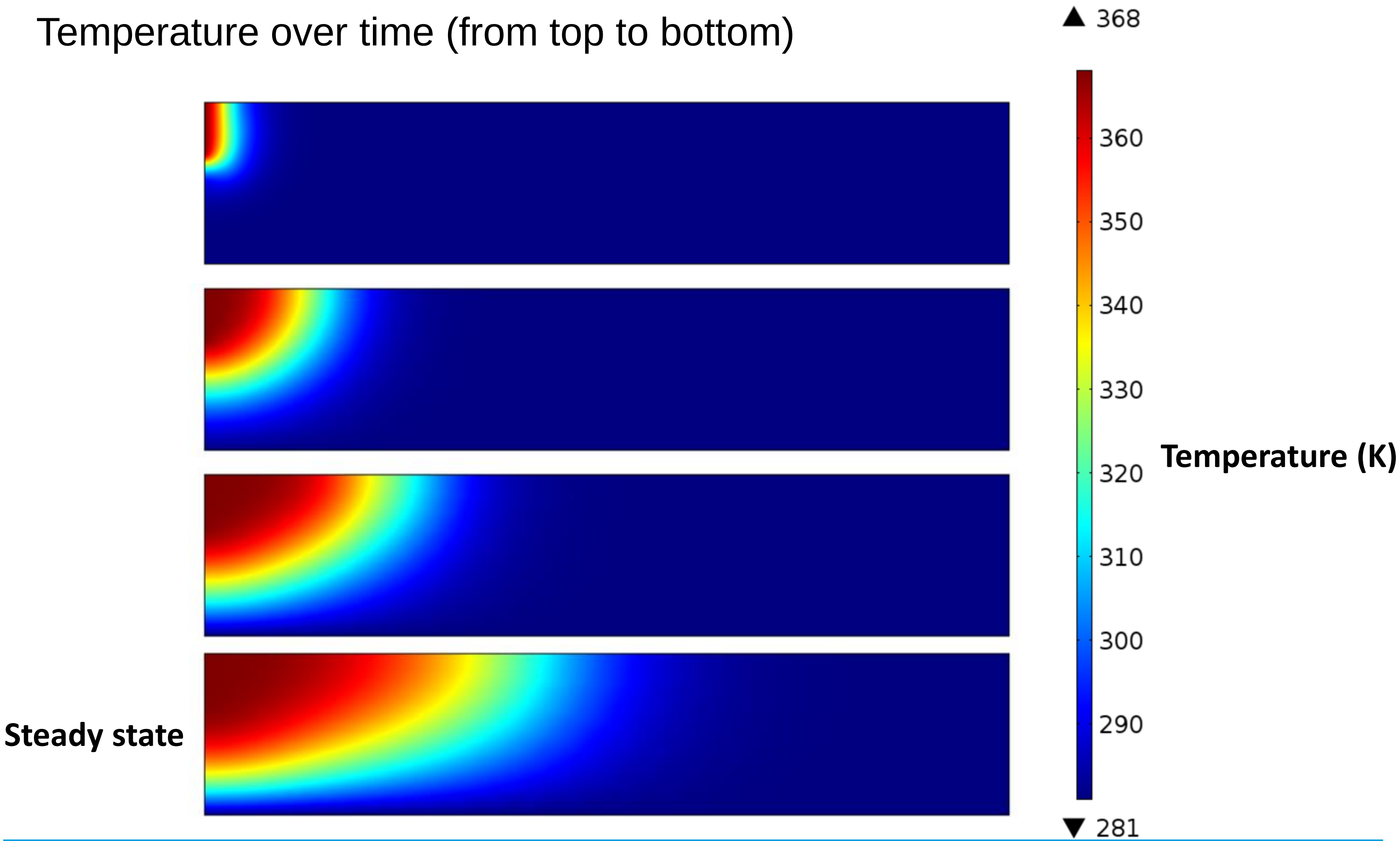
2-phase Model preliminary results

- Wetting phase saturations over time (from top to bottom)



2-phase Model preliminary results

- Temperature over time (from top to bottom)



Take-away messages

- Two different modeling approaches for methane-hydrate dissociation were presented.
- CSTR-based model is quick and provide a platform for 3-phase solutions which are not currently feasible in reservoir models.
- Parameter study is only feasible with 2D or CSTR models since the computational time of the 3D models is very high.
- In turn, 3D models enable us to discover some details that 2D models can’t show.

Thank you for your attention and see you at Poster #8