Gas Mobility Control Techniques during CO_2 Sequestration in Cranfield

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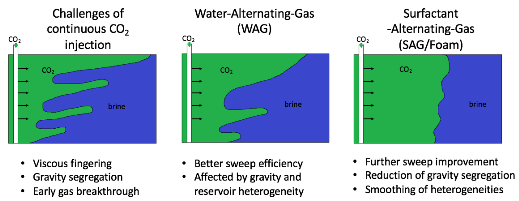
Introduction

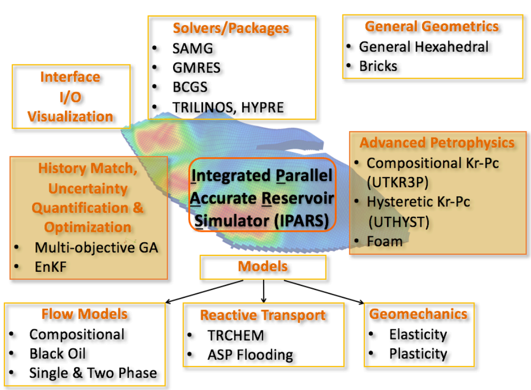
- Unexpected CO2 plume migration along high permeability flow paths during large scale sequestration of CO_2 in subsurface geologic formations is a major risk that adversely affects the selection of candidate sited that may otherwise be suitable for storing large volume of greenhouse gases.



- Foam has been proven to be effective for flood conformance control during enhanced oil recovery and CO_2 storage processes. In situ generation of foam serves to block gas migration along high permeability pathways and improves incomplete vertical sweep due to gravity segregation. This technology is attractive due to its low water and chemical additives requirements.
- UT in-house parallel compositional reservoir simulator (IPARS) can model both compositional flow and geomechanics. Advanced three-phase relative permeability (UTKR3P) and hysteresis (UTHYST) models have been implemented and coupled with foam models in IPARS to more accurately simulate WAG and SAG processes.
- **Objective:** This study investigates the efficacy for plume conformance control in the Cranfield site by field-scale simulations of WAG and SAG processes.

Integrated Parallel Accurate Reservoir Simulator (IPARS)

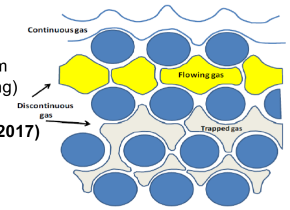
- Workhorse for multiphysics, parallel, field scale simulations
- Coupled geomechanics, flow, reactive transport and thermal models
- Fractured reservoirs: hydraulic and natural fracture treatment
- Advanced well models: horizontal and deviated wells
- Visualization: Paraview, Tecplot



Foam Modeling

Background on Foam

- Foam is dispersion of gas in liquid phase
- Stabilized by surfactant or nanoparticles
- Steam foam, CO_2 foam, N_2 foam, HC foam
- Reduce gas mobility (increase gas trapping)

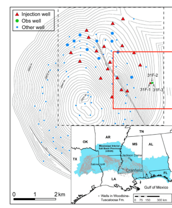


Foam Modeling in IPARS (Lotfollahi et al 2017)

- Weak foam at low shear-rates
- Foam transition from weak to strong foam
- Non-Newtonian rheology
- Foam hysteresis

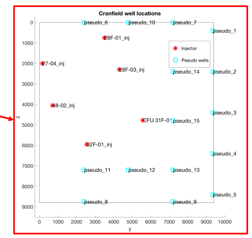
Reservoir Model of Cranfield Site

- **Contour map of Cranfield site**

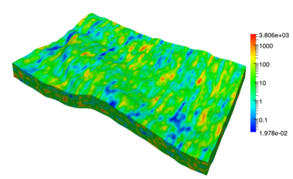


red rectangle shows the area of simulation

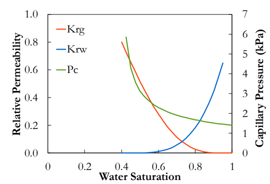
- **Simulated well locations**



- **x-permeability**



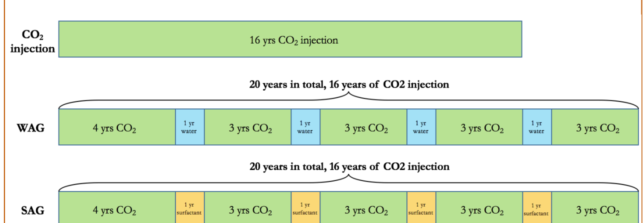
- **Pc, Kr (Delshad et al 2013)**



Numerical Model of Cranfield field test	
Model Type	Compositional model
Reservoir size	9400×8800×80 (ft)
Number of grid blocks	188×176×20
Initial water saturation	1.0
Initial pressure	4650 (psi)
Initial temperature	257 (°F)
Salinity	150,000 (ppm)

PVT data	CO_2	Brine
Critical temperature (°R)	547.56	1120.23
Critical pressure (psia)	1070.4	3540.9
Compressibility factor	0.255	0.2
Acentric factor	0.224	0.244
Molecular weight (g/g mol)	44.01	18.01
Volume-shift	-0.19	0.065
Binary interaction coefficients	0.09	0.09

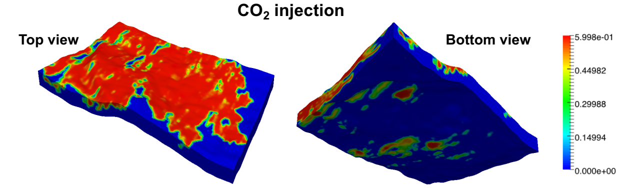
CO_2 Sequestration Simulated Injection Schemes



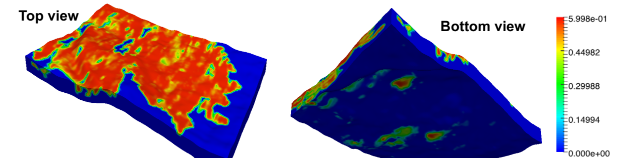
Simulation Results

- **Gas saturation profiles at the end of injection**

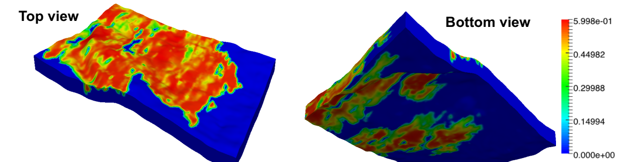
CO_2 injection



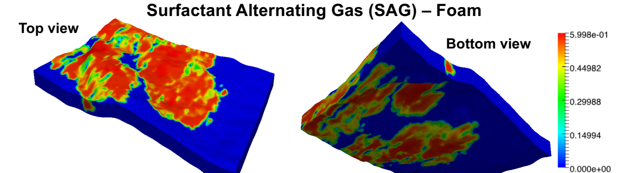
Water Alternating Gas (WAG) – without Hysteresis Modeling



Water Alternating Gas (WAG) – with Hysteresis Modeling



Surfactant Alternating Gas (SAG) – Foam



- **Field Statistics**

Injection Senario	CO_2 injection	WAG w/o hysteresis	WAG with hysteresis	SAG
Field average CO_2 concentration	0.24	0.22	0.28	0.31
Cum CO_2 injected (MMscf)	2.10E+05	2.10E+05	2.10E+05	2.03E+05
Cum CO_2 lost from boundaries (MMscf)	7.15E+04	8.19E+04	4.00E+04	2.05E+04
CO_2 lost from boundaries (%)	34	39	19	10.1

Conclusions

- In this study, CO_2 storage volume increased by 15% and 24% of total CO_2 injection volume during WAG and SAG processes, respectively.
- It is essential to model relative permeability hysteresis during cyclic processes (WAG, SAG here) to capture the physics of the problem more accurately.
- During SAG process, foam is generated in the high permeability streaks and upper layers with higher CO_2 flow rate and diverts the CO_2 flow into low permeability regions and bottom layers leading to more efficient areal and vertical sweep efficiency.