Probabilistic Risk Assessment of CO_2 Trapping Mechanisms in a Sandstone CO_2-EOR Field in Northern Texas, USA

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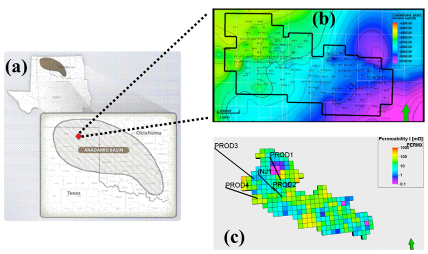
Introduction

- **Problem**: CO_2 storage forecasting is affected by uncertainty due to heterogeneity, including permeability and porosity.
- **Goal**: Quantifying uncertainty of CO_2 storage and evaluating CO_2 trapping mechanisms in a sandstone CO_2-EOR field.
- **Method**: Reduced Order Models (ROMs) via Polynomial Chaos Expansion (PCE).

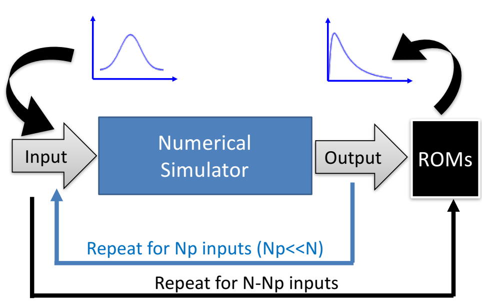
Model Description

- Farnsworth Unit (FWU), northern Texas
- Morrow B sandstone
- 28×22×20=12320 cells
- 1 injector-centered five-spot pattern
- 20 yrs. of CO_2-EOR + 20 yrs. of monitoring (no inj./prod.)



Methods

Reduced Order Models (ROMs)



Polynomial Chaos Expansion (PCE)

$$y_i = M(\boldsymbol{x}) = \alpha_0 B_0 + \sum_{j=1}^{M} \alpha_j B_1(x_j) + \sum_{j=1}^{M}\sum_{k=1}^{j} \alpha_{jk} B_2(x_j, x_k) + \sum_{j=1}^{M}\sum_{k=1}^{j}\sum_{h=1}^{k} \alpha_{jkh} B_3(x_j, x_k, x_h) \cdots$$

$$[B_1, \ldots, B_d]|_{\boldsymbol{x}} \longrightarrow \boldsymbol{B} \longrightarrow \boldsymbol{B\alpha} = \boldsymbol{y}$$

$$\boldsymbol{\alpha} = (\boldsymbol{B}^T \boldsymbol{B})^{-1} \boldsymbol{B}^T \boldsymbol{y}$$

Parameter Uncertainty

- Porosity & Permeability
- 1000 realizations generated by variogram model and sequential Gaussian simulation

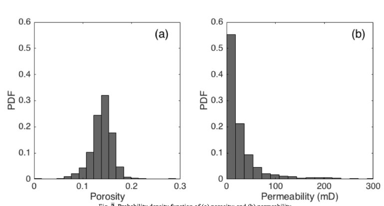


Fig. 2. Probability density function of (a) porosity; and (b) permeability.

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$$\text{output} = M\ (\text{porosity, permeability})$$

Output	Time
CO_2 mass distribution in oil phase	@ The end of simulation (40 yrs.)
CO_2 mass distribution in supercritical phase	
CO_2 mass distribution in aqueous phase	

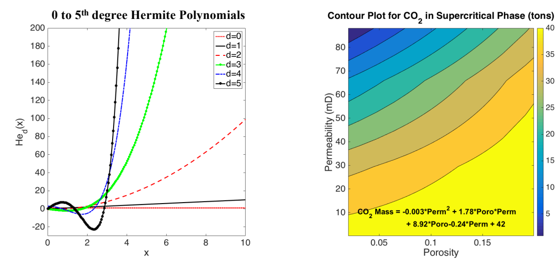
- Use **25** Eclipse simulations to "train" the ROMs
- Use the ROMs for simulating **1000** realizations

Results & Discussion

Predicted by 25 Eclipse Simulations

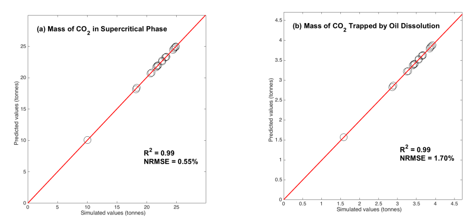
	Mean	Standard Deviation	Minimum	Maximum
Hydrodynamic trapping (tonnes)	174,760	1,812	170,790	178,330
Oil dissolution trapping (tonnes)	60,970	486	60,240	61,750
Aqueous dissolution trapping (tonnes)	2,740	15	2,700	2,750

Basis Function and An Example of ROM

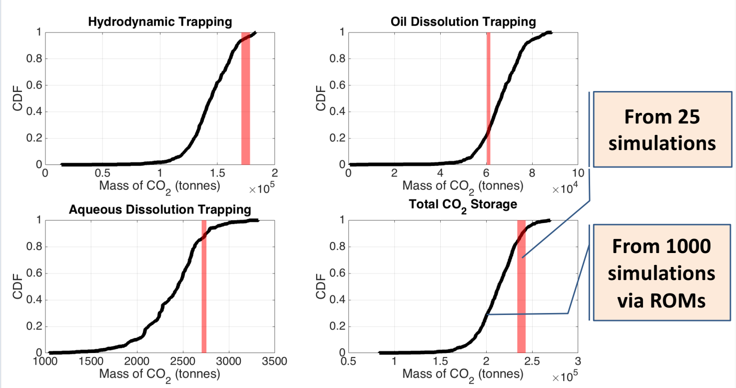


Quality of ROMs

- R^2
- Normalized Root Mean Square Error (NRMSE)



CDF of CO_2 Storage



Key Results

- Hydrodynamic trapping sequesters the most injected CO_2 at the FWU (121,400~166,860 tonnes), followed by oil dissolution trapping (55,303~76,816 tonnes), and aqueous dissolution trapping (1979~2751 tonnes).
- With one five-spot pattern and 20 years of CO_2-EOR, the CO_2 stored in the FWU is between 185,430 tonnes and 239,170 tonnes, demonstrating the significant uncertainty in total CO_2 storage induced by parameter heterogeneity of porosity and permeability.