Detection of CO_2 leakage and Unknown CO_2 Migration Path Using Machine Learning and Ensemble Kalman Filter

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Objectives

Under high uncertainty in geologic models,

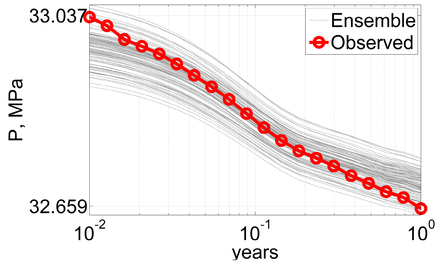
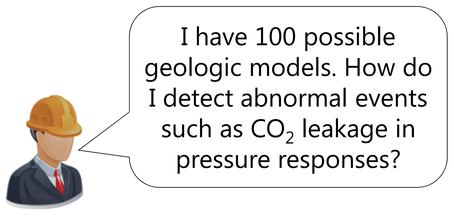


Fig 1. Injection pressure history. The observed pressure is within the ensemble band.



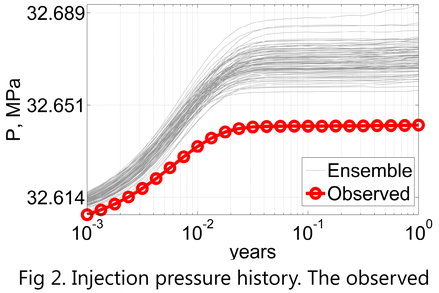
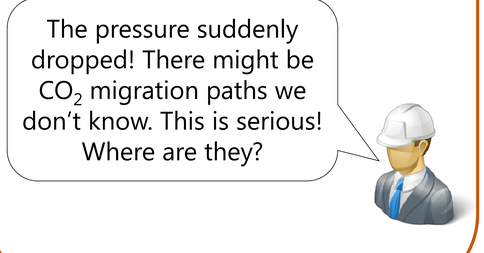


Fig 2. Injection pressure history. The observed pressure is not within the ensemble band.



Detection of Abnormal Events

- ❑ Confidence interval or ensemble band
  - ✓ Normal: within the interval
  - ✓ In Fig 1, the abnormal pattern of the observed pressure is not detectable because it is within the interval
- ❑ Principal Component Analysis

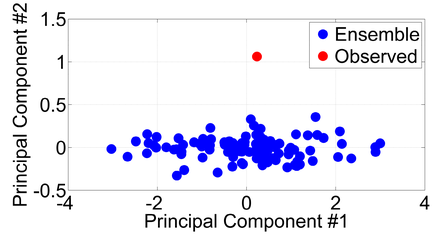


Fig 3. Feature space of the pressure data shown in Fig 1.

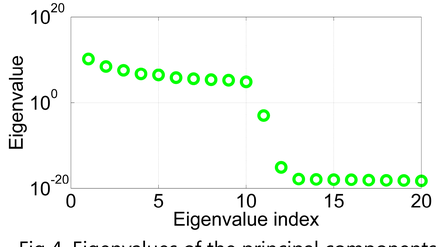


Fig 4. Eigenvalues of the principal components

- ✓ The observation can be detected as an anomaly in the feature space shown in Fig 3.
- ✓ Anomaly can happen because of unknown CO_2 migration path, wrong boundary conditions, or wrong k distributions

A Synthetic Case for Detection of Unknown CO_2 Migration Path

- ❑ Model description
  - ✓ Based the Cranfield model
  - ✓ Unstructured grids: better to model faults and fractures
  - ✓ ϕ and k: correlation = 0.7

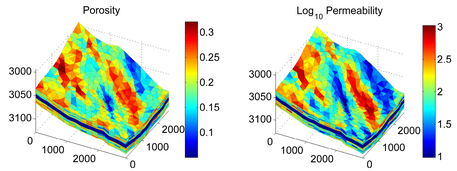


Fig 5. φ and log_{10} k of one of 100 models for the synthetic case

- ✓ Simulated using PFLOTRAN
  - o Open source
  - o Support unstructured grids
  - o Parallel computation using Stampede and Lonestar5 of Texas Advanced Computing Center (TACC)

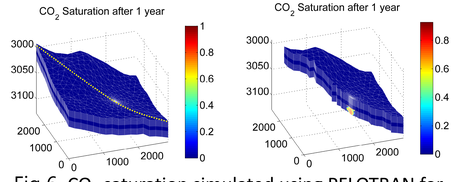


Fig 6. CO_2 saturation simulated using PFLOTRAN for the model shown in Fig 5.

  - o Seal rock between two reservoir units
  - o CO_2 is injected into the below reservoir unit
- ✓ True model
  - o CO_2 leakage through a highly permeable feature on the seal layer where the mesh is different
  - o The prior models do not know about the permeable feature

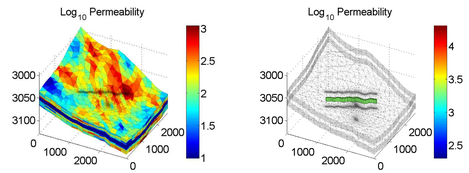


Fig 7. Log_{10} k of the true model and the highly permeable feature on the seal layer

  - o Abnormal events in the pressure responses

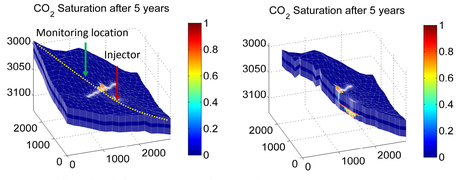


Fig 7. CO_2 saturation of the true model

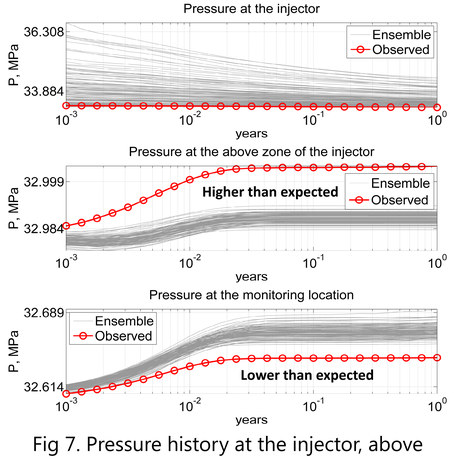


Fig 7. Pressure history at the injector, above zone, and monitoring location

Summary

- ❑ Although pressure responses are within a ensemble band, they can be abnormal events
- ❑ The abnormal events can be detected in the feature space computed using PCA
- ❑ A synthetic case was built based on the Cranfield model to test detecting unknown CO_2 migration paths

Future Works

- ❑ Automatic anomaly detection in feature spaces using machine learning techniques
- ❑ Detection of unknown CO_2 migration path using Ensemble Kalman filter (EnKF)
  - ✓ Add possible CO_2 leakage pathways stochastically to prior models
  - ✓ Monitoring network design for fast leakage detection

Acknowledgement

Authors acknowledge the financial support by the DOE through the project DE-FE0026515