Detecting leakage locations from pressure monitoring data in the overlying aquifer

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**Question:** How much monitoring data is required to detect and locate a leak

**Analytical location studies**
- Theis approximations (Javandel et al., 1988)

**Computational leak detection studies**
- Pressure transients: Chabora (2009)
- SnR: Sun & Nicot (2012/2013)

**Computational location studies?**

**Relevant research methods**
- Oil field data assimilation: Oliver (1996), Sarma et al. (2006)
- CCS data assimilation: Cameron and Durlofsky (2013)
Problem setup

10.9 km

160 m

Potential monitoring well locations (red lines)
Overlying aquifer
Cap rock
Storage formation

CO₂ injectors (green lines)
Modeling notes

- Grid: 25x25x(8+1+4)
- Inject 5 Mta for 30 yrs
- Equilibrate for 470 yrs
- Large boundary region (39x39x13)
- Residual & dissolution trapping, ECO2N EOS
- Het. capillary pressure
- Simulate using ECLIPSE CO2STORE
Geologic and leak uncertainty

- Heterogeneous $\phi$ with
  
  $$k = ae^{b\phi}$$

- Realizations from variogram

- Leaks characterized by
  
  $$(i, j, k_z)^{\text{leak}}$$

Location:

$$(i, j)^{\text{leak}}$$

Permeability:

$$k_z^{\text{leak}} \in [0.005, 100] \text{ md}$$
Data assimilation process

- Match pressure for 5 ‘true’ models with noise
- Unknowns are:
  - Permeability field ($K_{L}$)
  - $(i, j, k_z)^{\text{leak}}$
- Use Particle Swarm Optimization
- Match always good
Question 1: How much temporal data needed

-A few months is enough to find location
-Noisy data better after 6 months

History matches use 9 multi-level monitoring wells in overlying aquifer
Leakage volume matches generally good

History matches use 9 multi-level monitoring wells in overlying aquifer
Question 2: how many monitoring wells needed

Data

– 12 months pressure from N wells in ‘true’ models
– Also with 0.1 psi noise

Method

– History match ‘true’ models for

- Analyze the average efficacy of history match
Results – One or two wells is mostly insufficient.  
– Four wells almost as good as nine  
– Noise helps again!
Result – Fluid leakage match good with few wells!
What about multiple leaks?

True

History match
Example 2 – multi-leaks

True

History match
Conclusions

• Data assimilation can match leak location to within 1 grid block (~ 400 m in this study) using 9 wells and 12 months

• Noise is important – regularizes overdetermined least squares

• 6-12 months data sufficient to detect/locate wells

• Leakage location available using ~ 3-4 wells

• Reasonable leakage volume estimate from only 1 well