

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

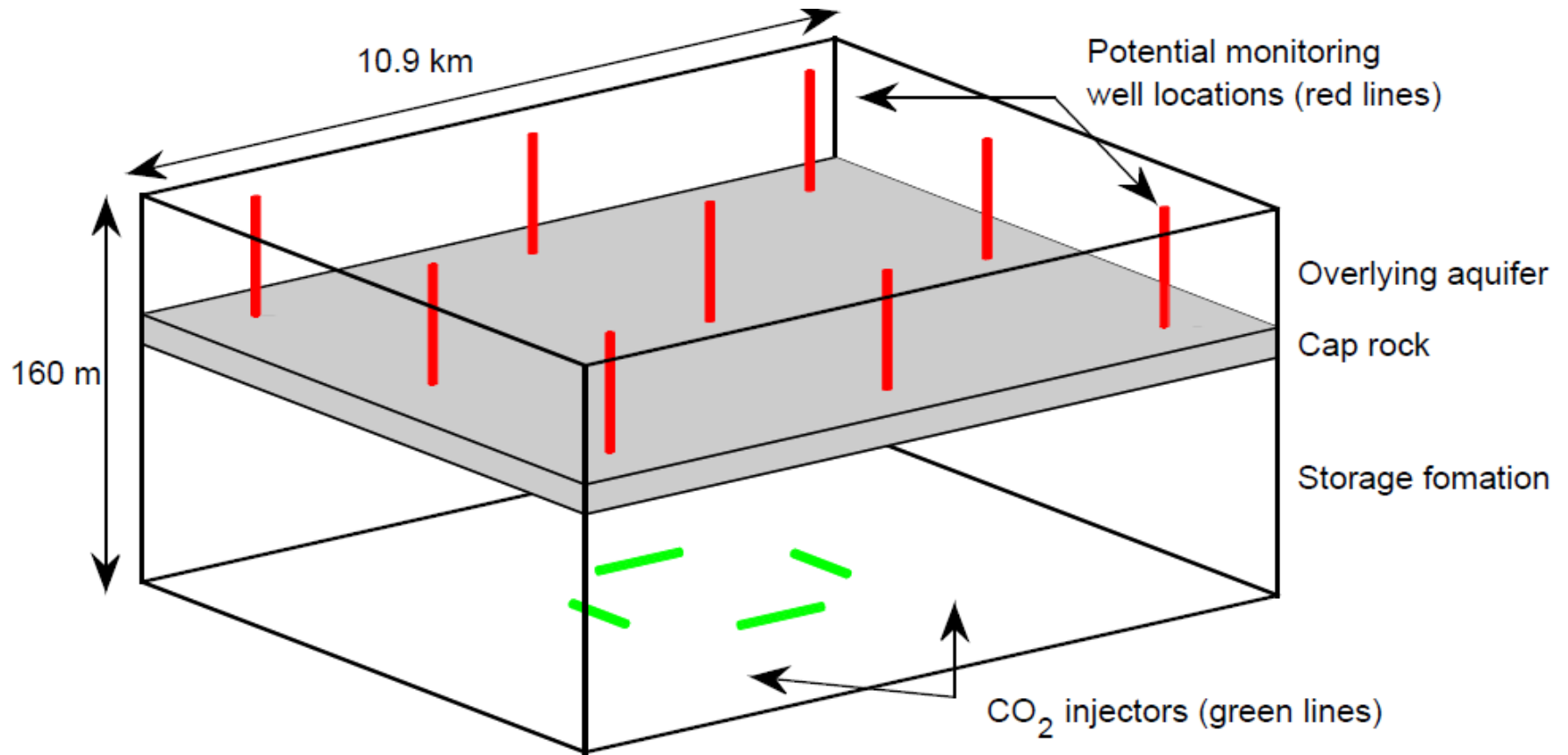
- Pressure transients: Chabora (2009)
- SnR: Sun & Nicot (2012/2013)

Computational location studies?

Relevant research methods

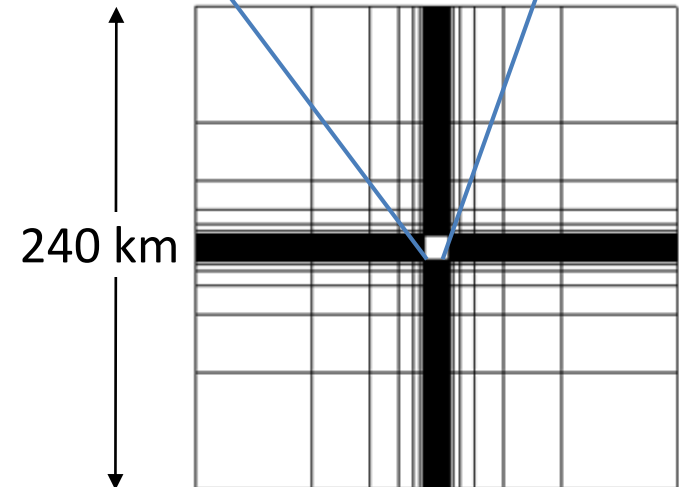
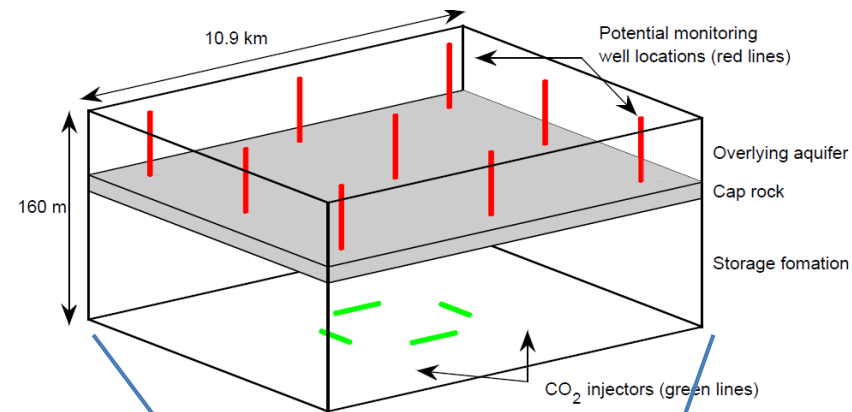
- Oil field data assimilation: Oliver (1996), Sarma et al. (2006)
- CCS data assimilation: Cameron and Durlofsky (2013)

Problem setup

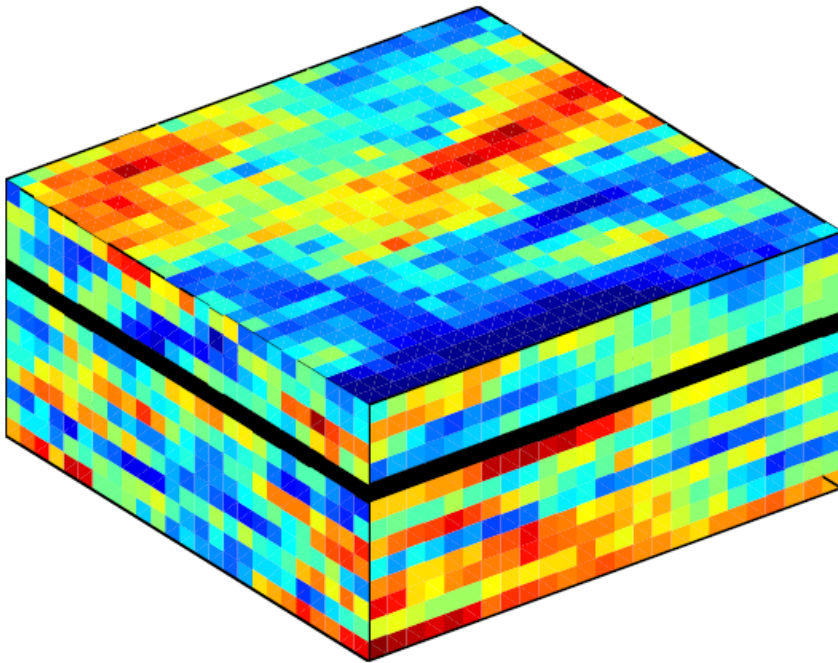


Modeling notes

- 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



Location:

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



Permeability:

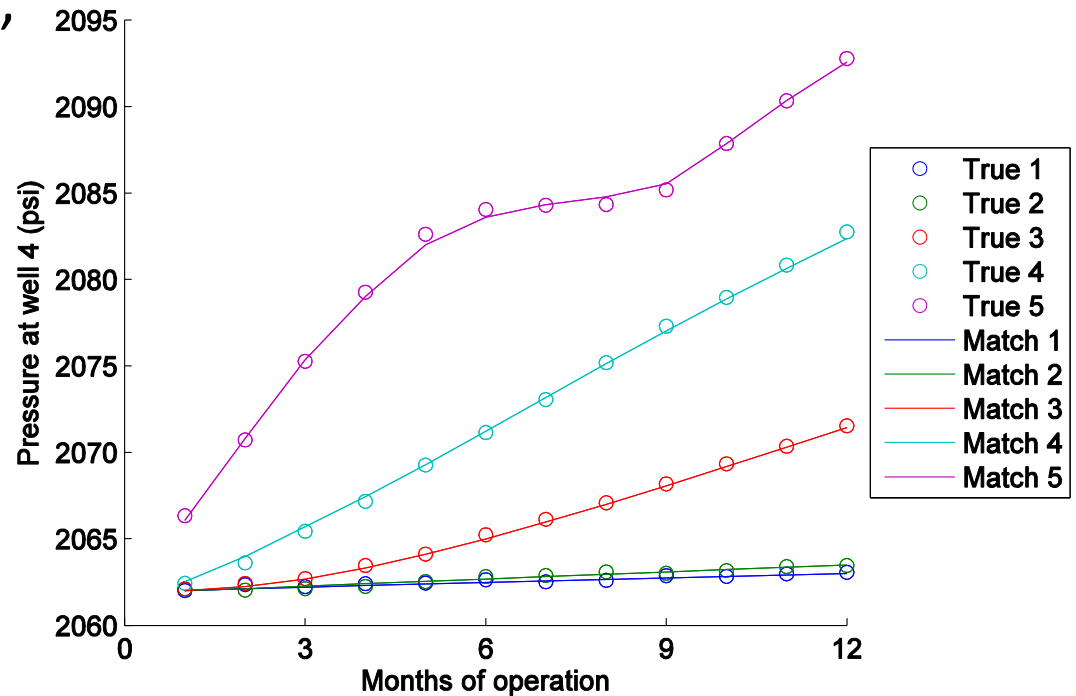
$k_z^{\text{leak}} \in [0.005, 100] \text{ md}$

- Heterogeneous ϕ with
$$k = a e^{b\phi}$$
- Realizations from variogram

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

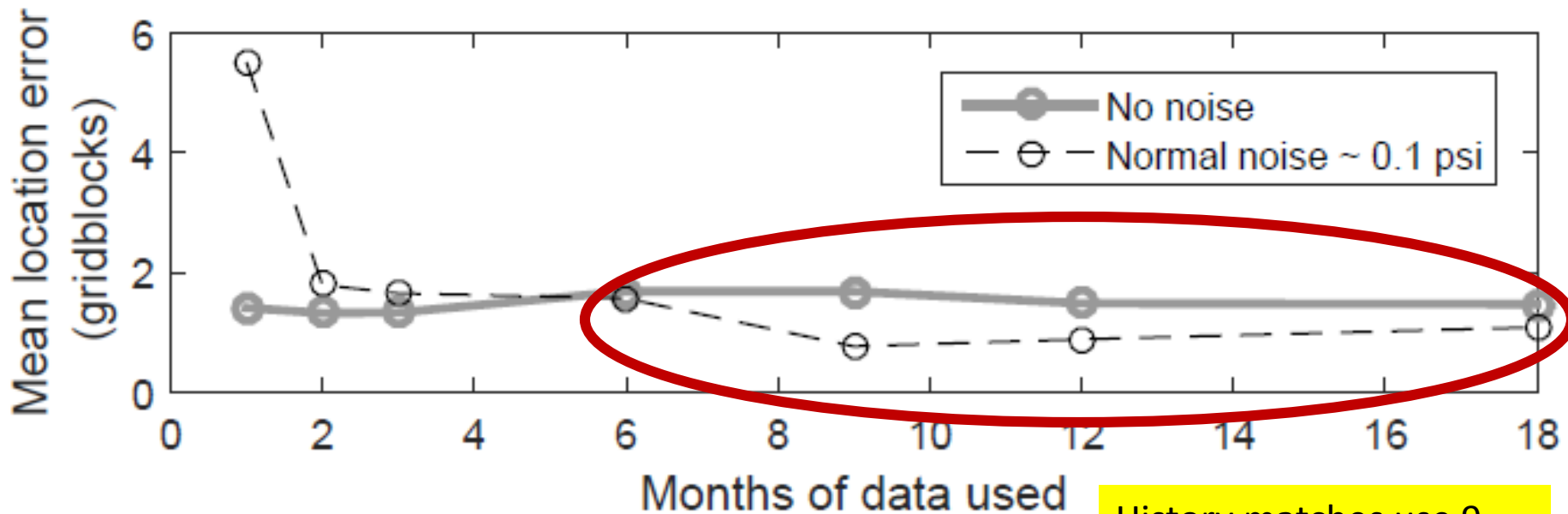
Data assimilation process

- 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



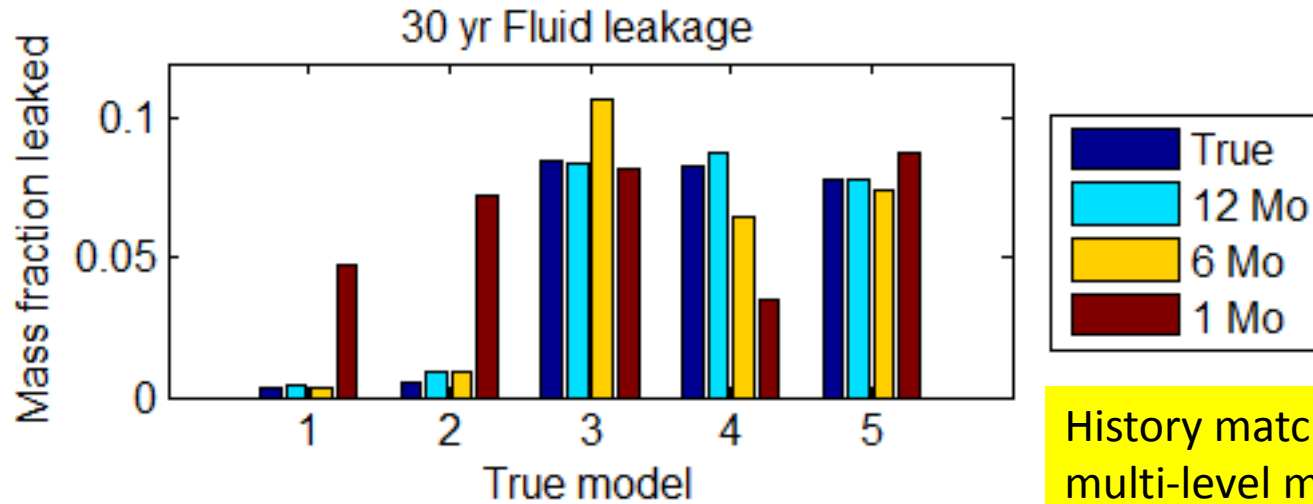
Question 1: How much temporal data needed

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

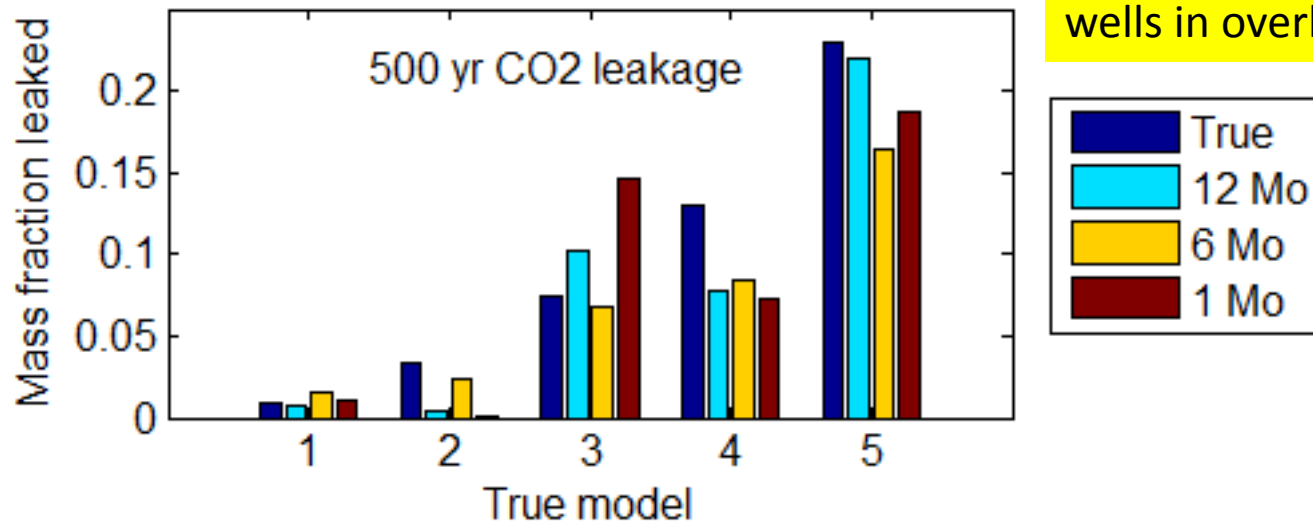


History matches use 9 multi-level monitoring wells in overlying aquifer

Leakage volume matches generally good



History matches use 9 multi-level monitoring wells in overlying aquifer



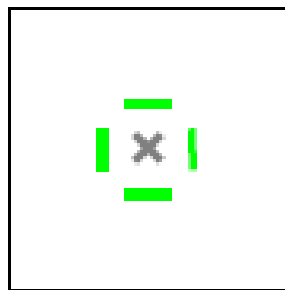
Question 2: how many monitoring wells needed

Data

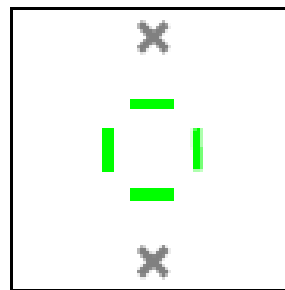
- 12 months pressure from N wells in ‘true’ models
- Also with 0.1 psi noise

Method

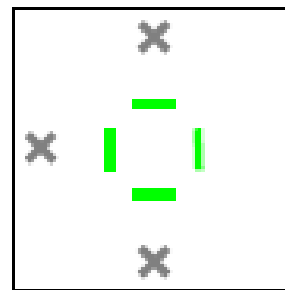
- History match ‘true’ models for



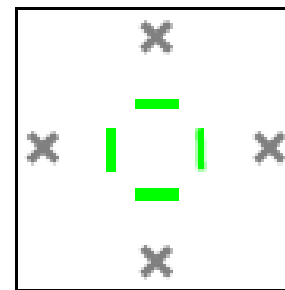
1 well



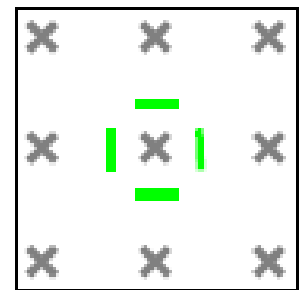
2 wells



3 wells



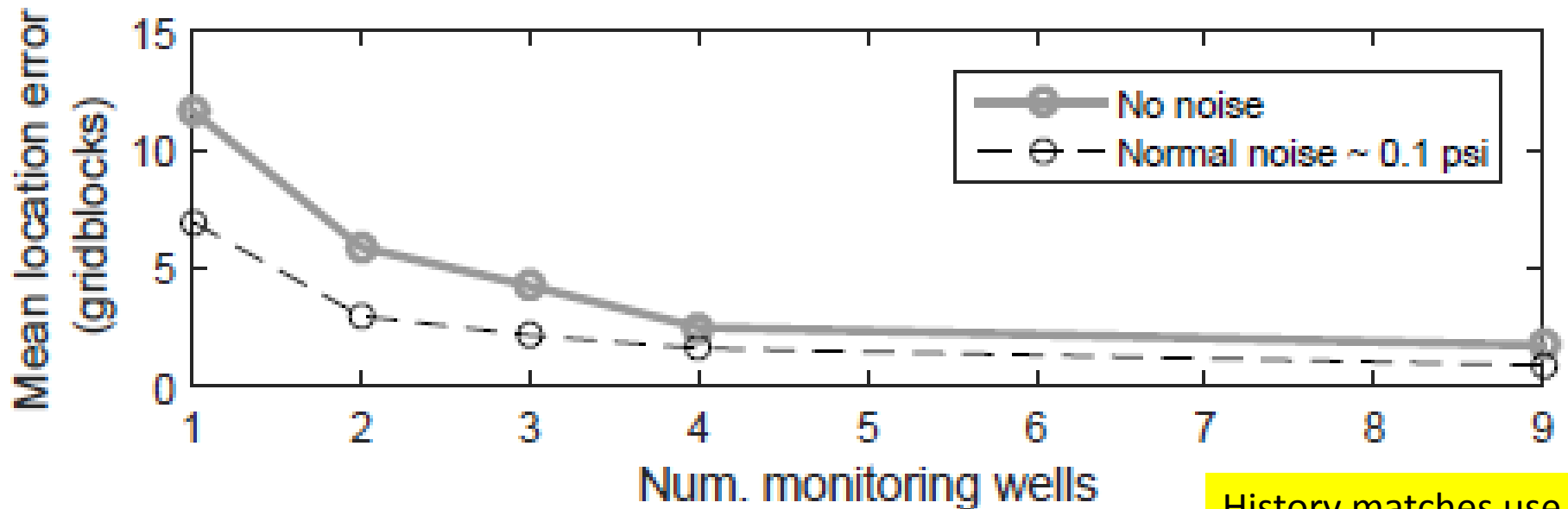
4 wells



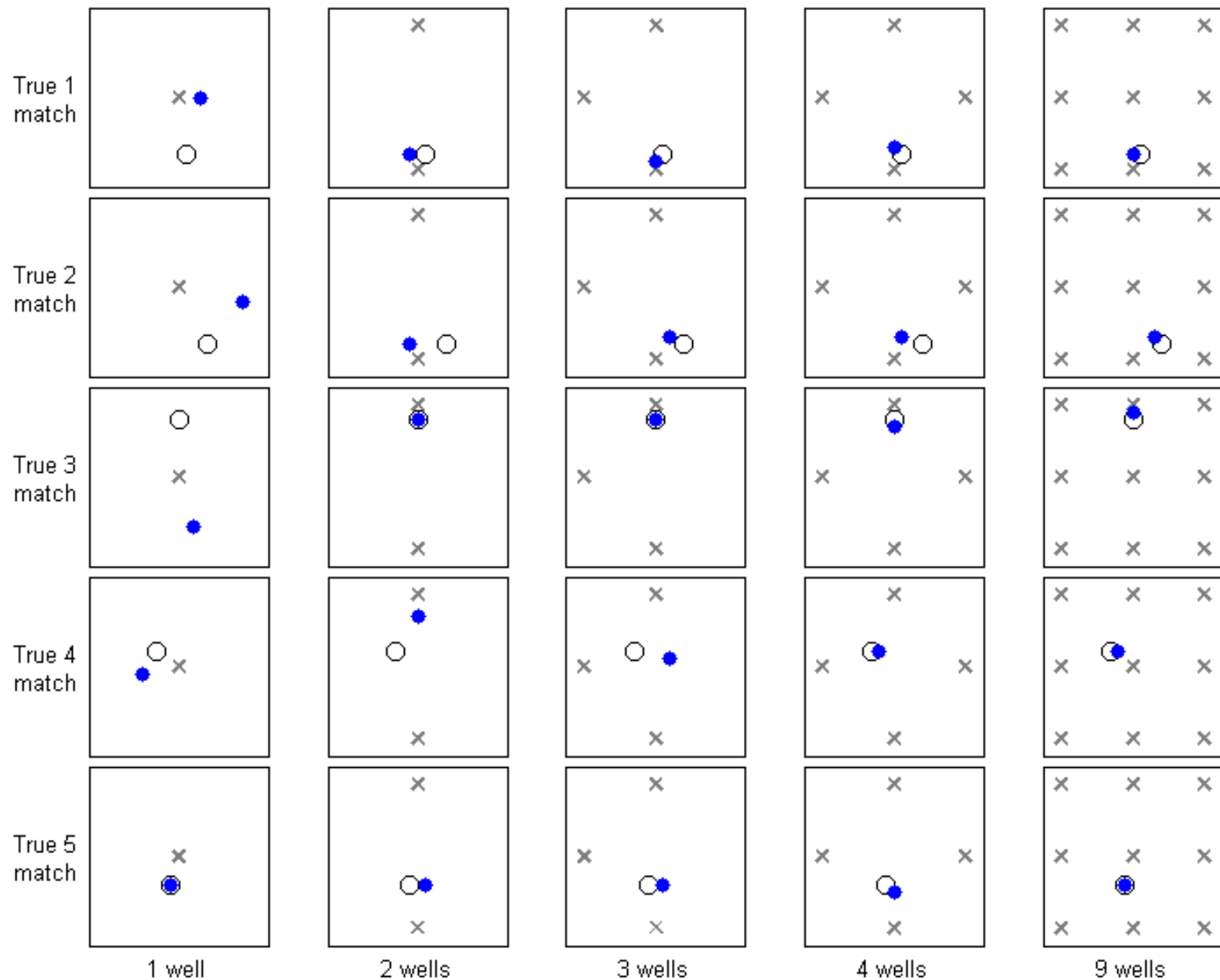
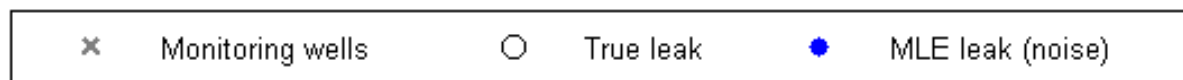
9 wells

- Analyze the average efficacy of history match

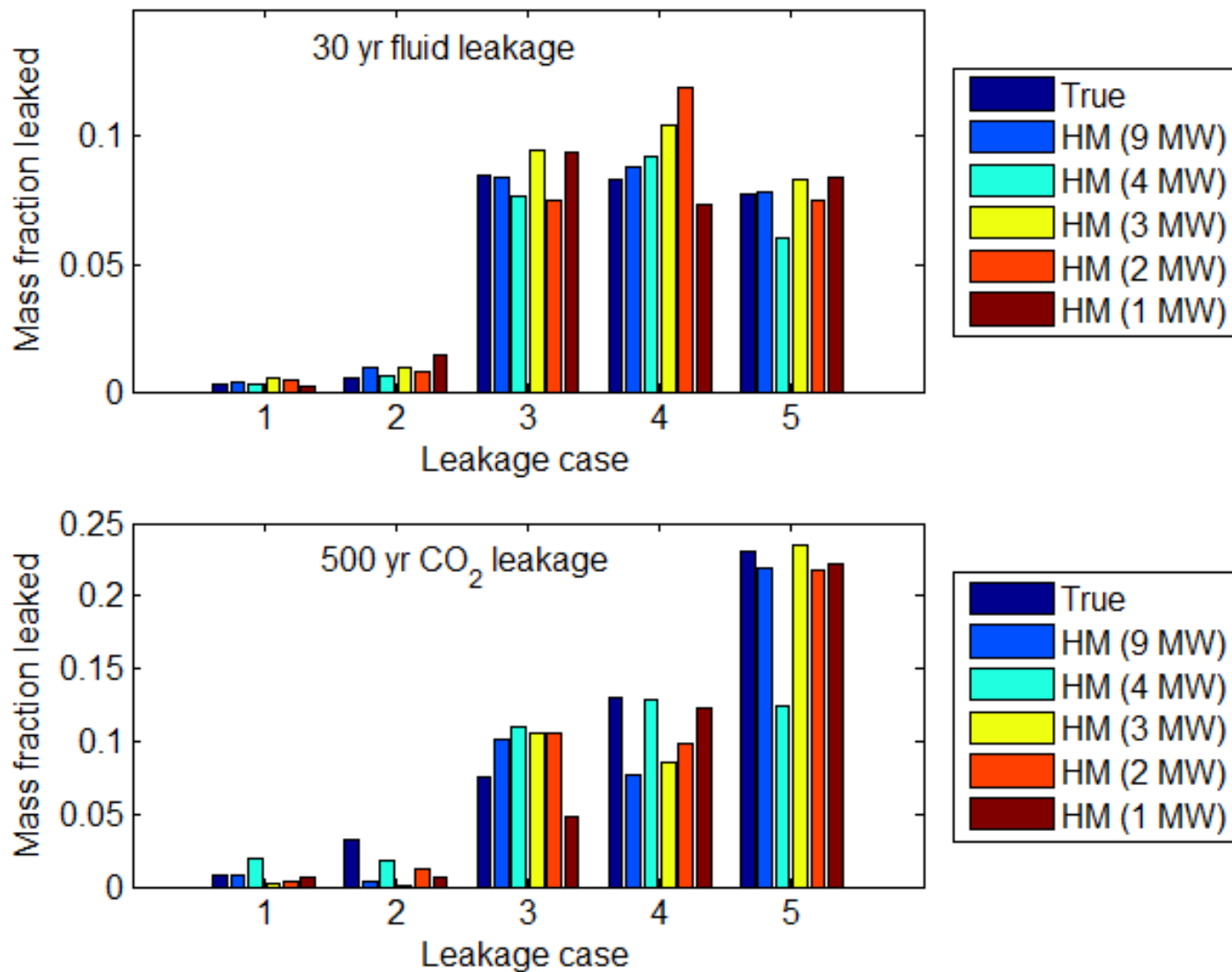
- Results – One or two wells is mostly insufficient.
- Four wells almost as good as nine
 - Noise helps again!



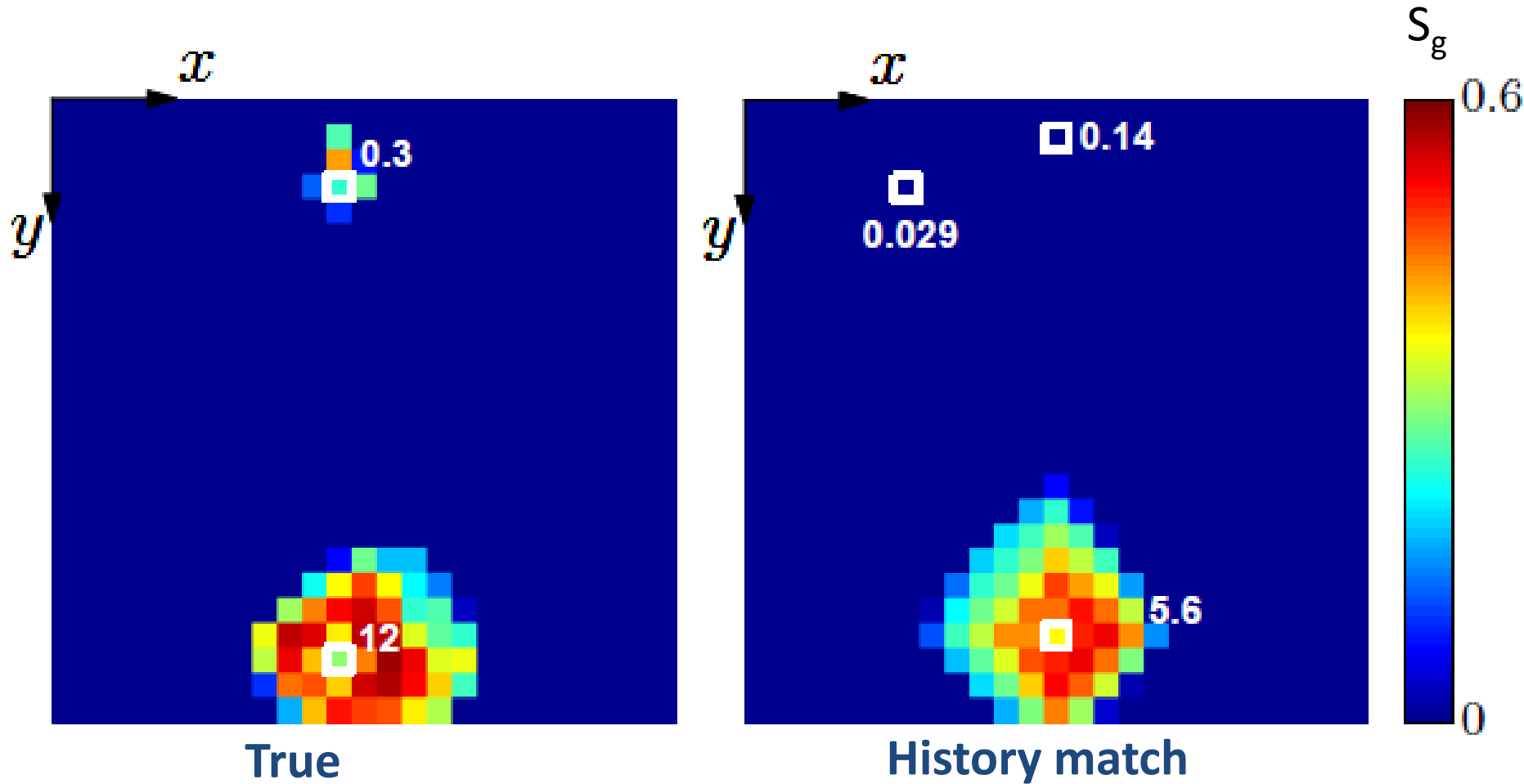
History matches use 12 months of data



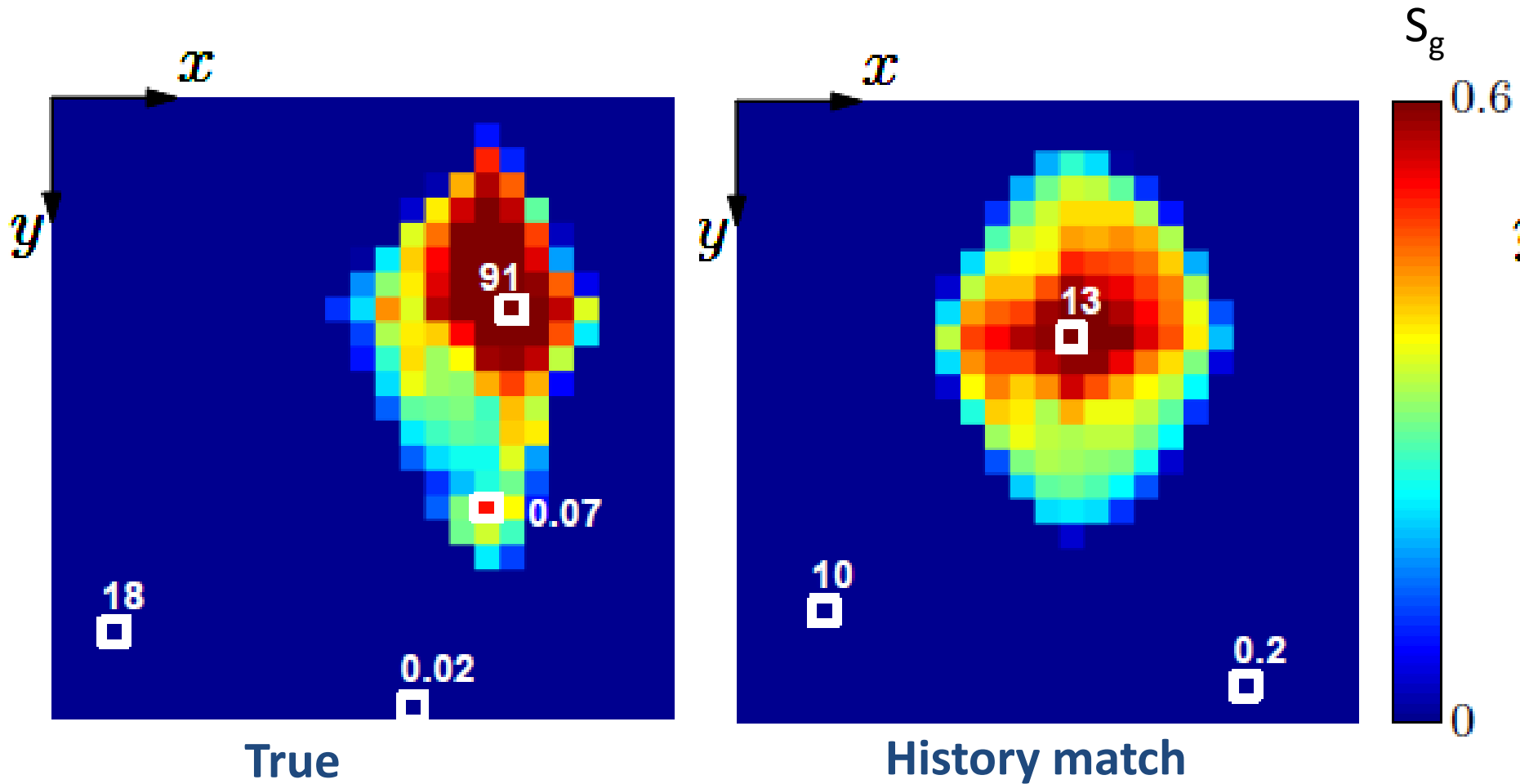
Result – Fluid leakage match good with few wells!



What about multiple leaks?



Example 2 – multi-leaks



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