PIDAS: Pressure-Based Inversion and Data Assimilation System for CO_2 Leakage Detection

DE-FE0012231

Alex Sun

Bureau of Economic Geology

University of Texas at Austin

U.S. Department of Energy

National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Developing the Technologies and
Infrastructure for CCS

August 12-14, 2014

Presentation Outline

- Benefit to the Program
- Project Overview
- Technical Status
- Accomplishments to Date
- Summary

Benefit to the Program

- The PIDAS project will develop, expand, and promote a ***well testing technology*** for leakage detection in carbon storage reservoirs. The technology, when successfully demonstrated, will provide an improvement over current monitoring technologies in both performance and cost.

Benefit to the Program

- Goals of Carbon Storage Program being addressed:
  – Develop and validate technologies to ensure 99 percent storage permanence
  – Develop Best Practice Manuals for monitoring, verification, accounting, and assessment

Project Overview: Goals and Objectives

- Demonstrate the utility of harmonic pulse testing for leakage detection through modeling, laboratory, and field tests
- Develop effective data assimilation and inversion algorithms
- Design optimal well testing strategies and publish a best practice manual for maximizing the utility of the developed PIDAS tool for early leakage detection

Project Overview:
Success Criteria and Decision Points

1. Theoretically bases of the technology are established and validated numerically

2. Technology is successfully validated in laboratory tests

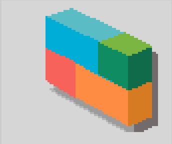
3. The technology is demonstrated in the field

Technical Status

PIDAS Work Flow

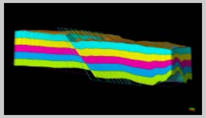
Modeling

- Forward
- Inverse



Lab Test

- Single phase
- Multiphase



Field Test

- Baseline
- Leak

Forward Modeling: Establish theoretical & numerical modeling methods
Inverse Modeling: Implement monitoring and detection tools

Harmonic Pulse Testing

- Less sensitive to ambient noise and to possible drift of the pressure gauge
- Can be applied with minimal interruption to normal production operations
- Can be used for both site characterization and leakage detection

Frequency Domain Analysis

- Transfer function →System characteristics

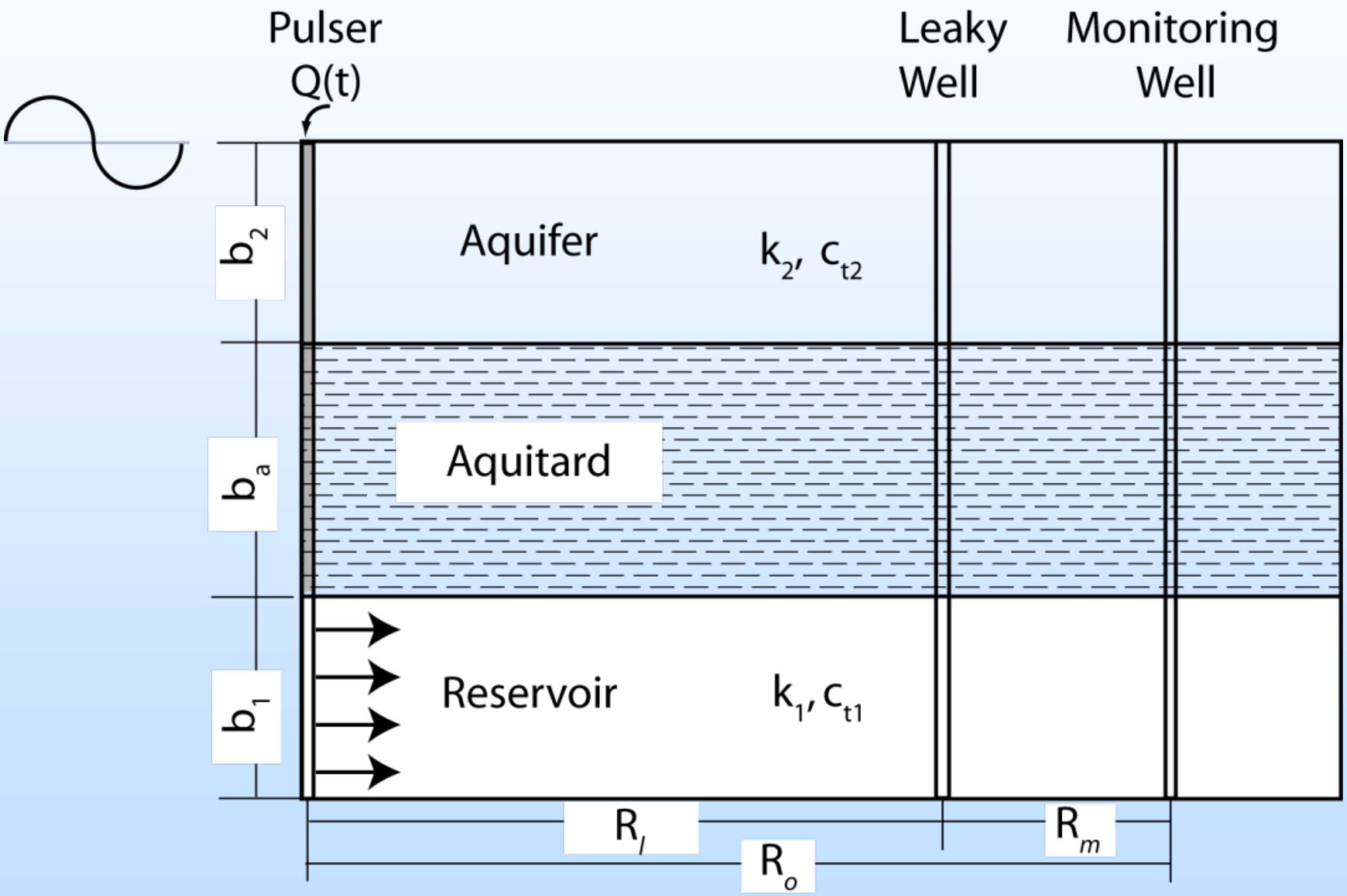
$$p_{obs}(t) = p_{inj}(t) * H(t) = \int_0^t p_{inj}(\tau) H(t-\tau)\, d\tau$$

$$\updownarrow$$

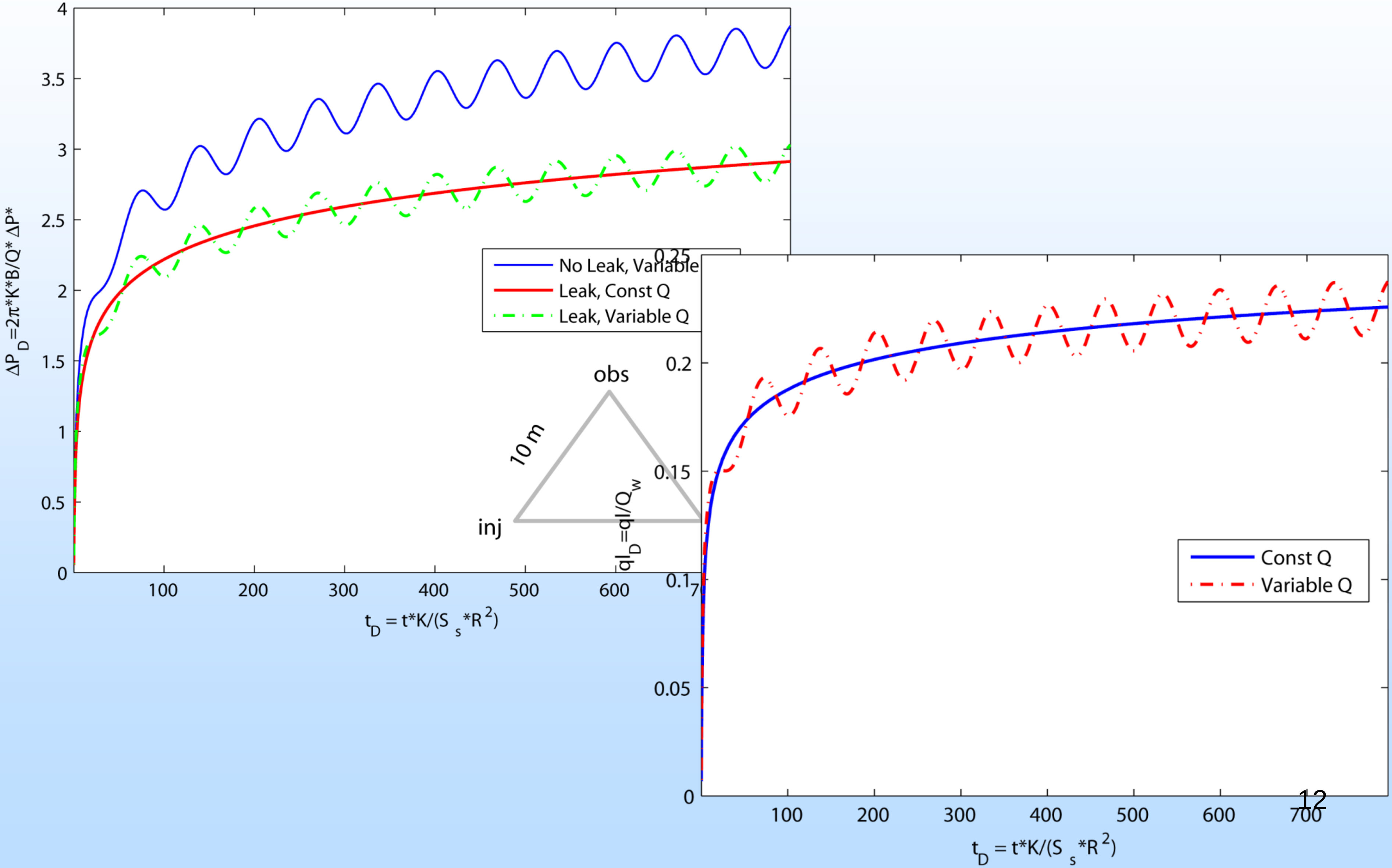
$$\hat{H}(\omega) = \frac{\hat{P}_{obs}(\omega)}{\hat{P}_{inj}(\omega)}$$

Amplitude ← → Phase

Forward Modeling

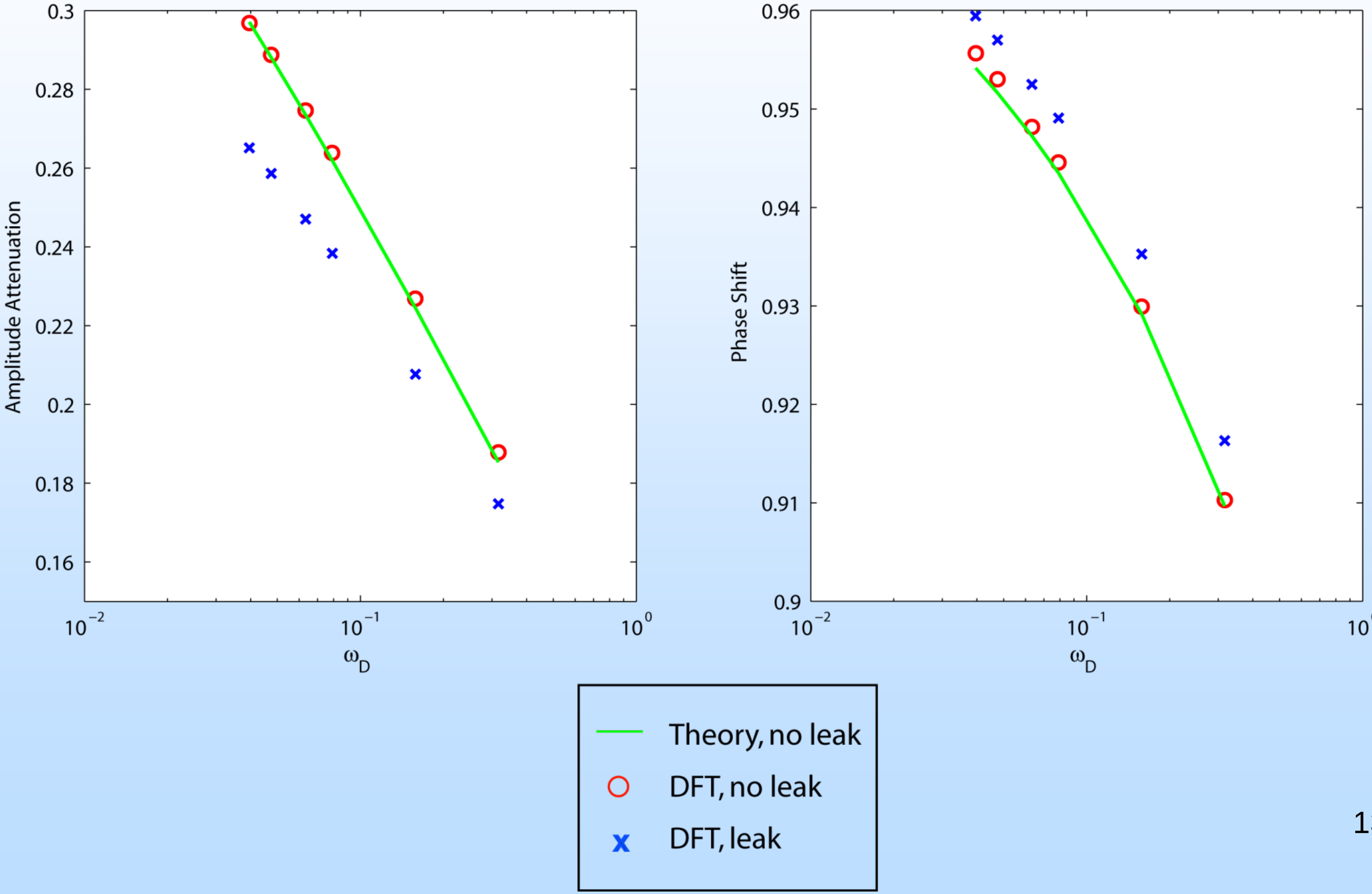


Forward Modeling



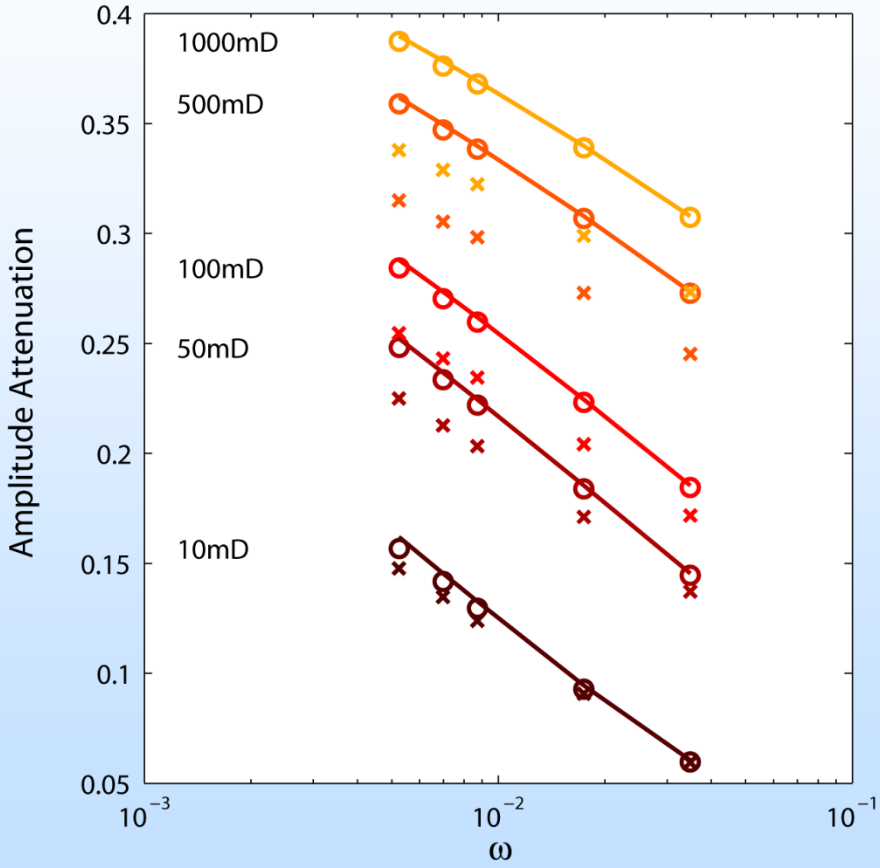
Frequency Chart

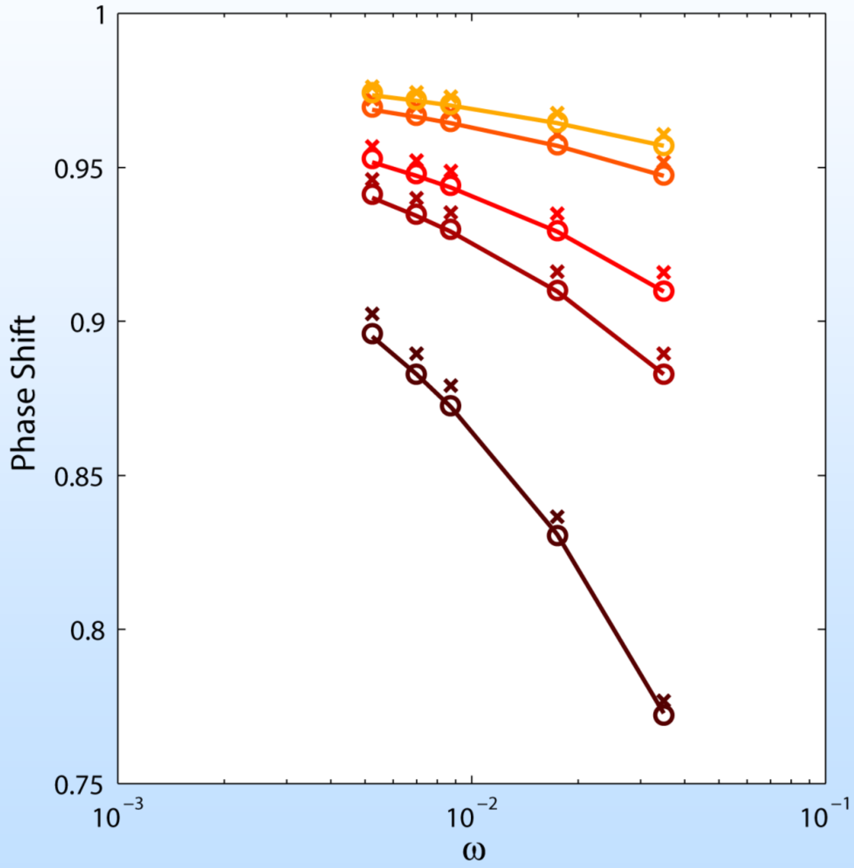
Base Case: total testing time 4 hrs; longest period 20 min



Sensitivity to Permeability

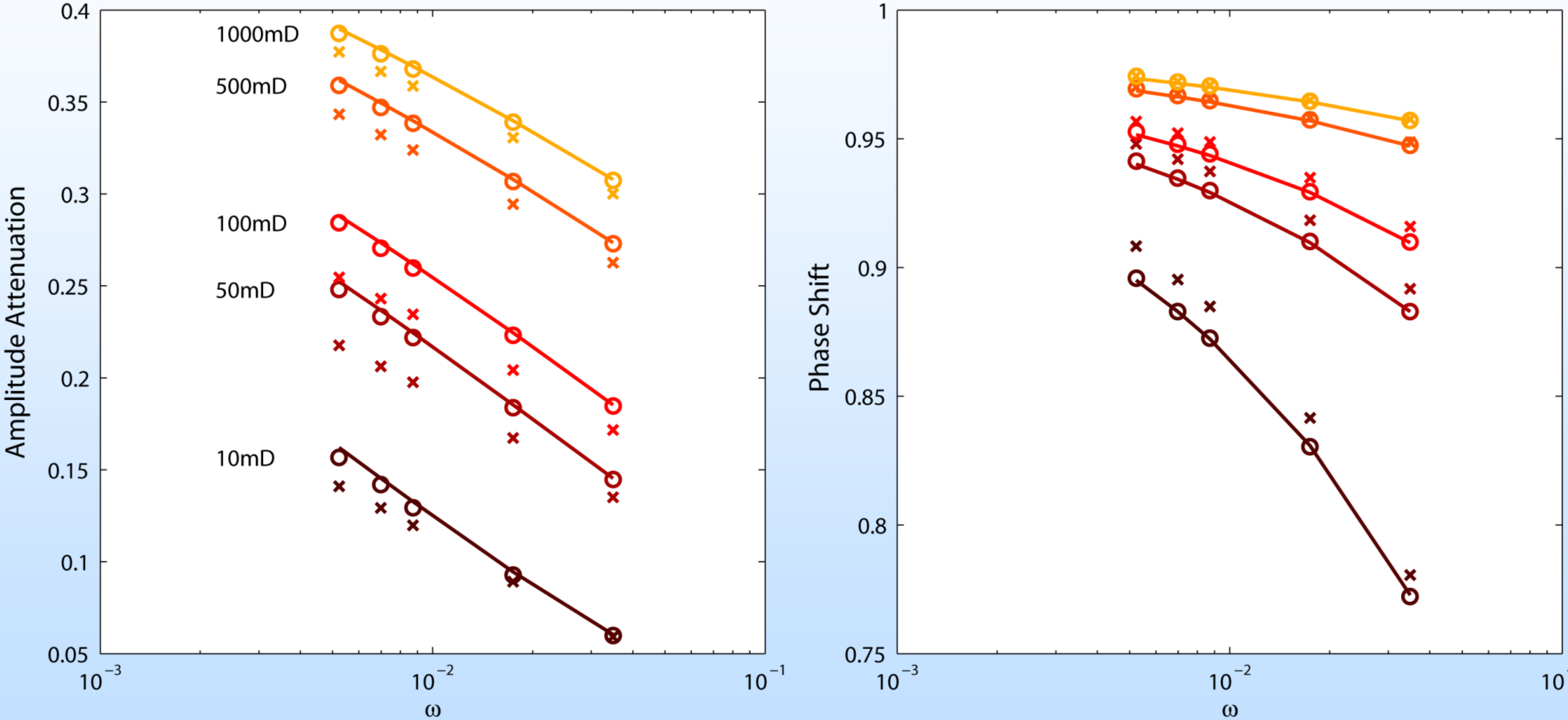
Fixed permeability ratio



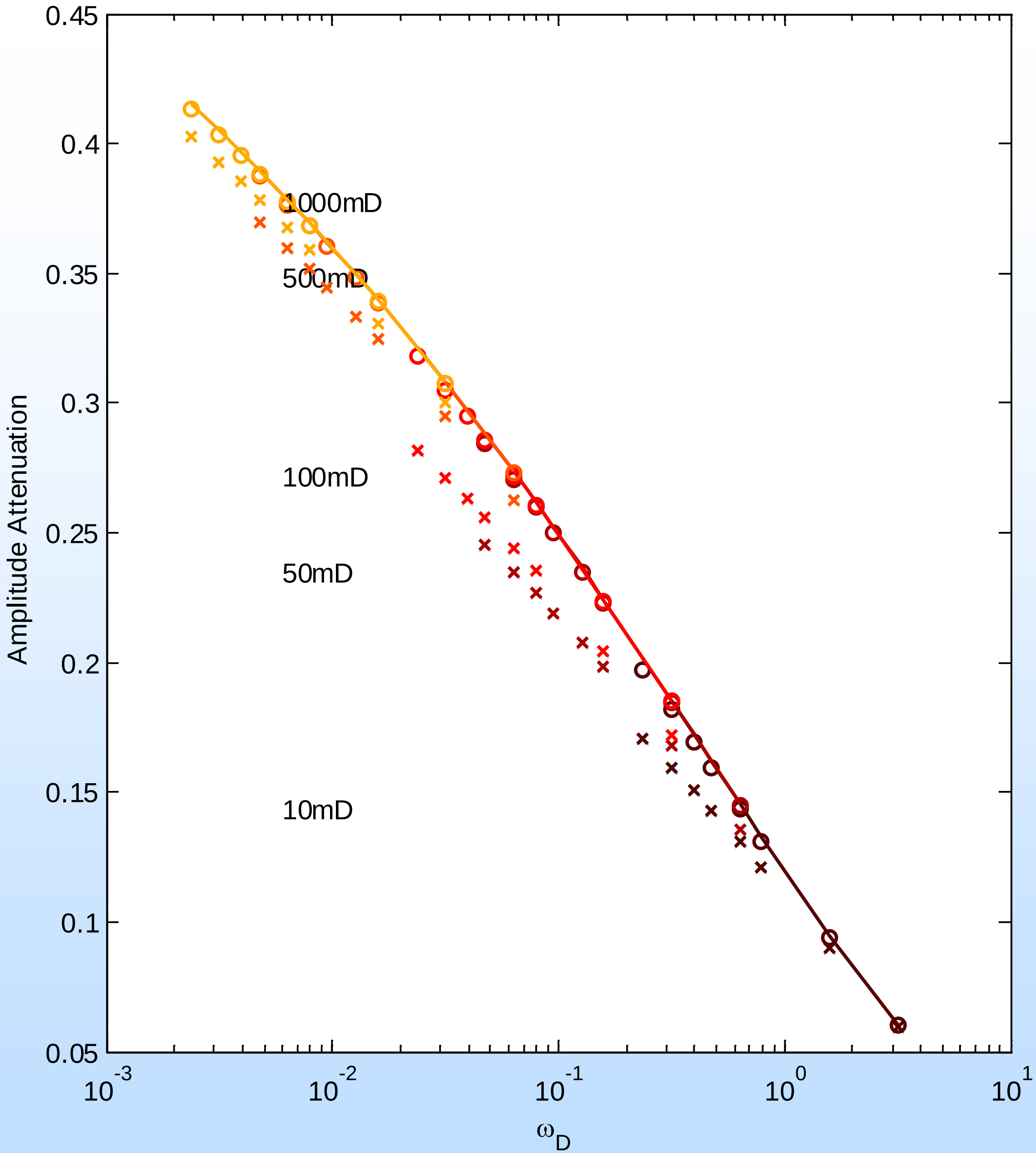


Sensitivity to Permeability

Fixed upper aquifer permeability

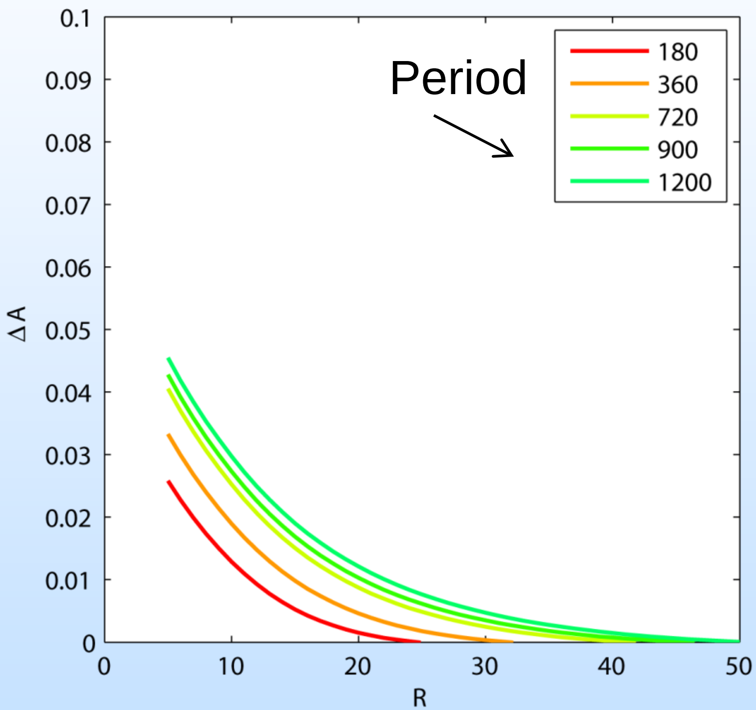


Dimensionless Frequency Chart

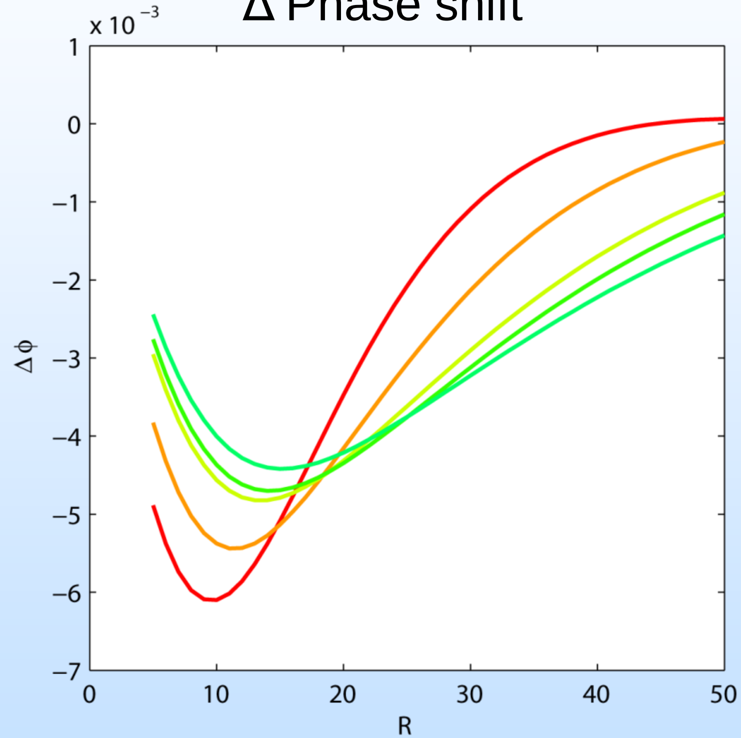


Sensitivity to Leak Distance

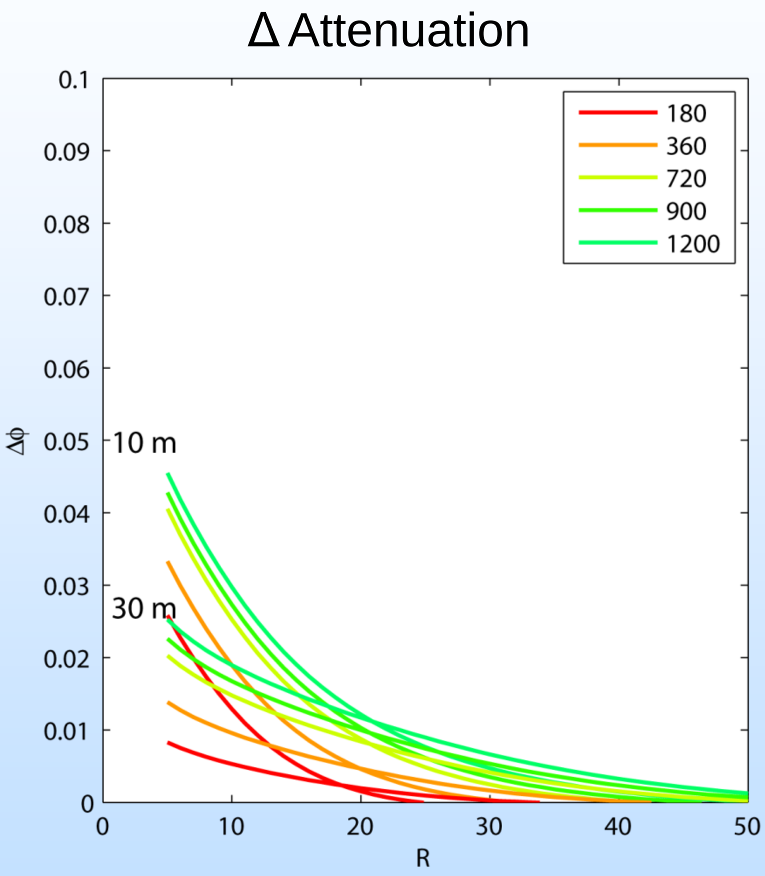
Δ Attenuation

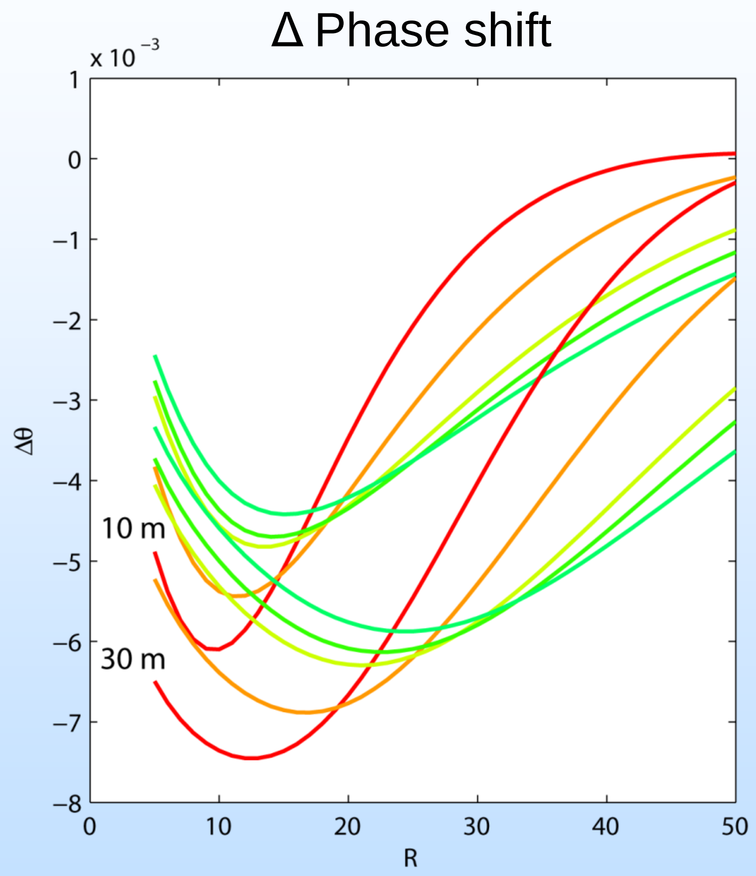


Δ Phase shift



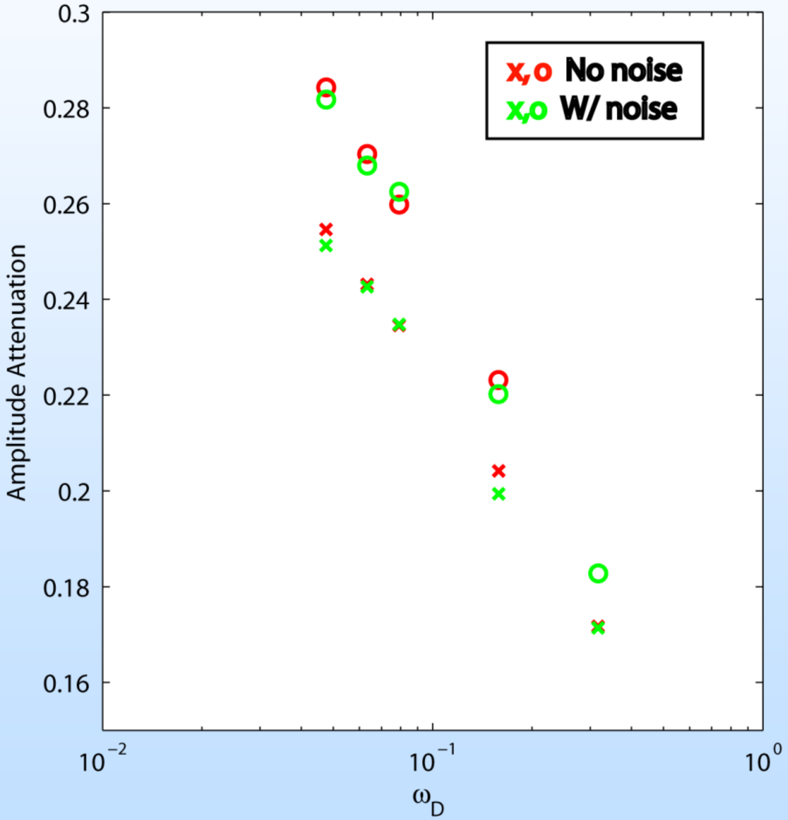
Sensitivity to Monitoring Loc

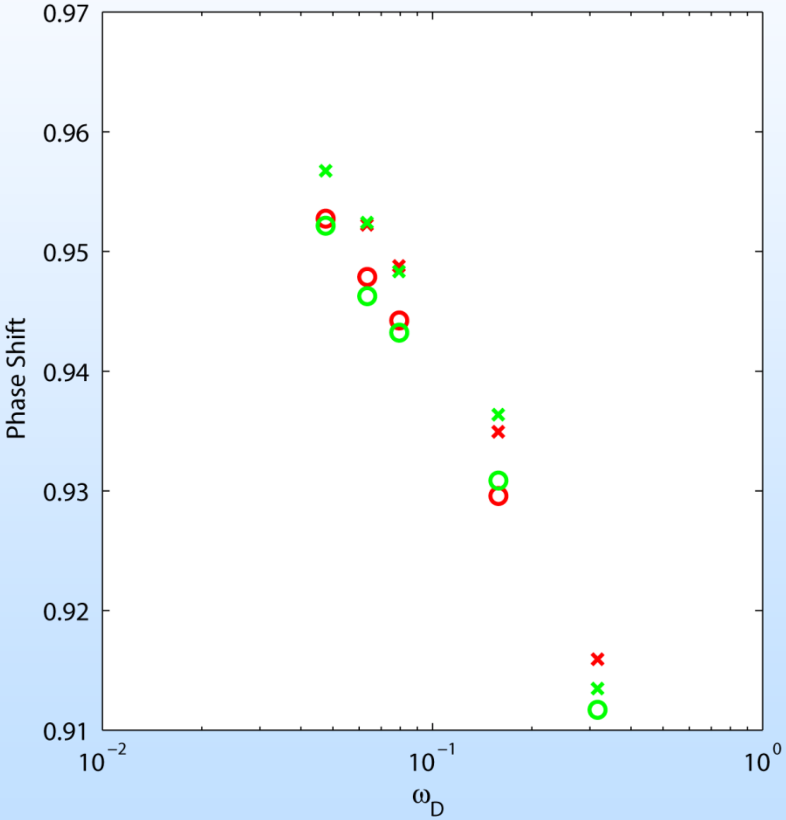




Sensitivity to Noise

5% measurement noise

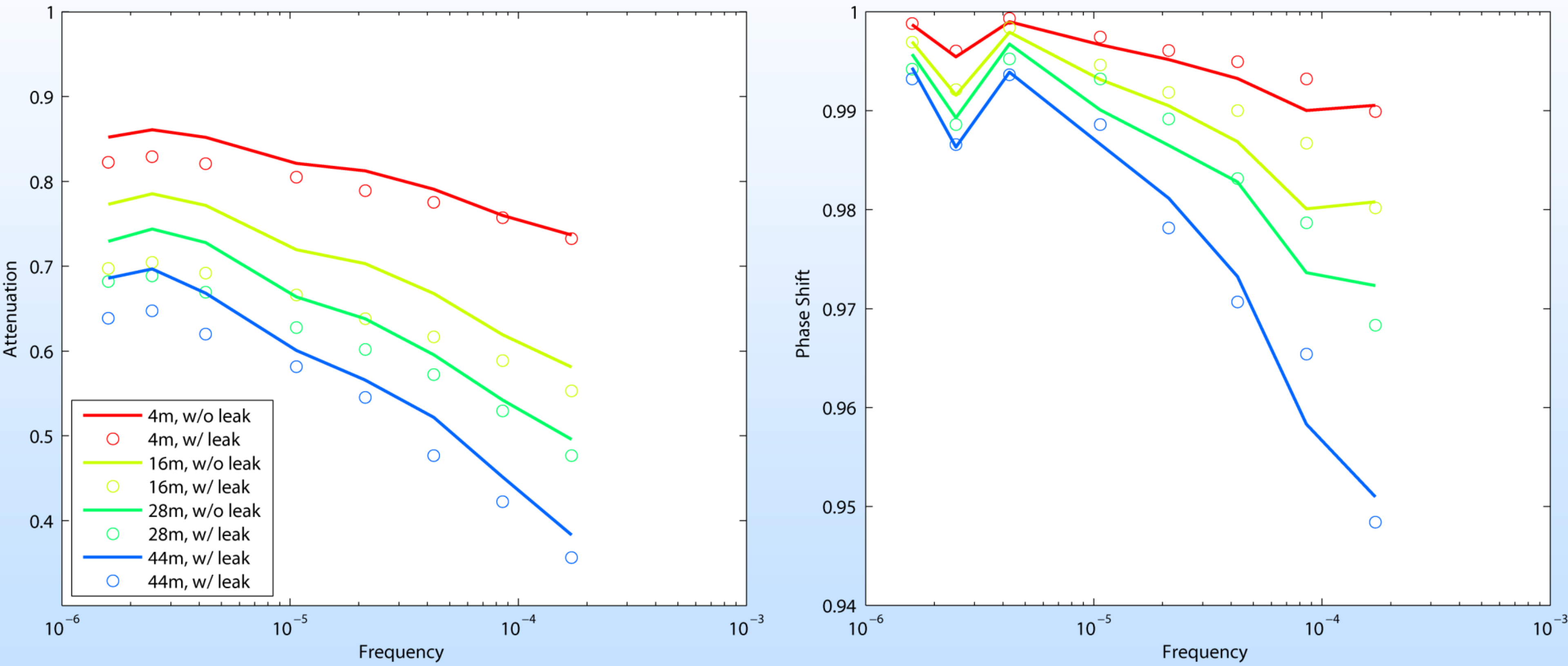




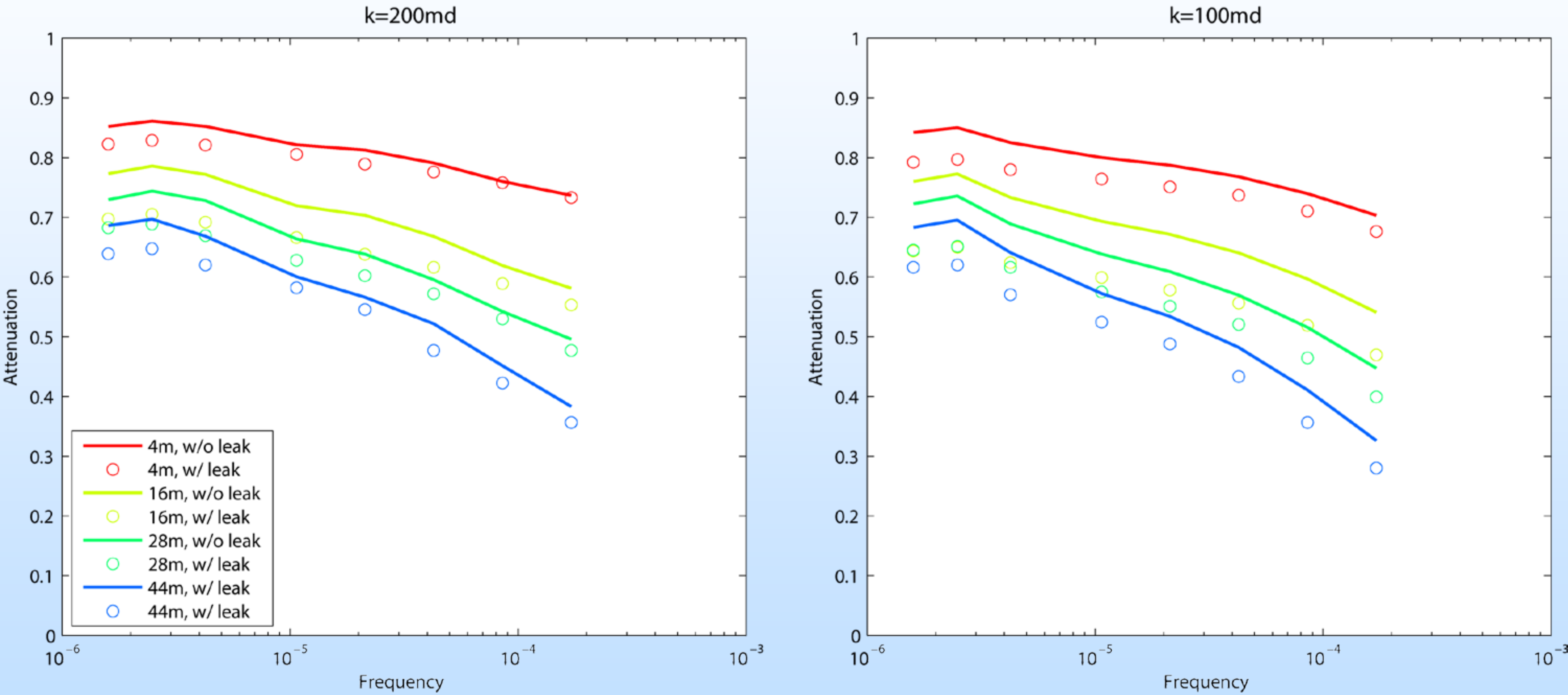
Multiphase Flow

- CO_2 injection into saline aquifer
- Simulation performed in CMG/GEM
- System dimensions: 2000x2000x 65 m (two aquifers each 30m thick, separated by a 5m confining layer)
- Pulse period: 0.5 – 30 d

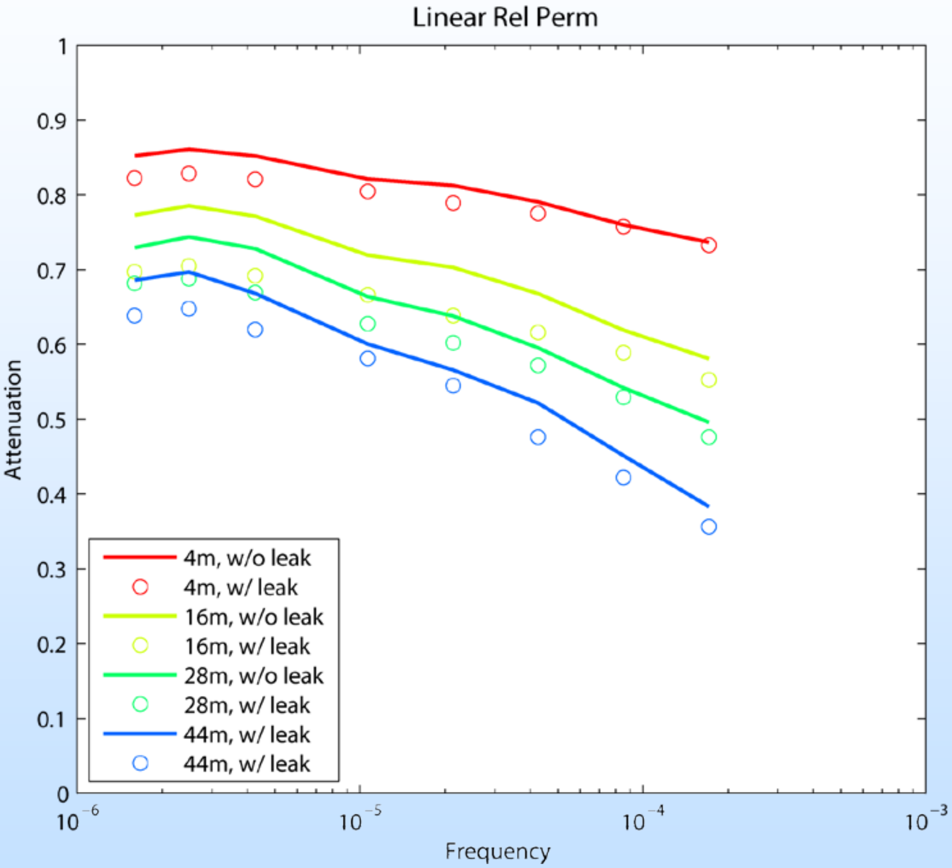
Sensitivity to Observation Loc

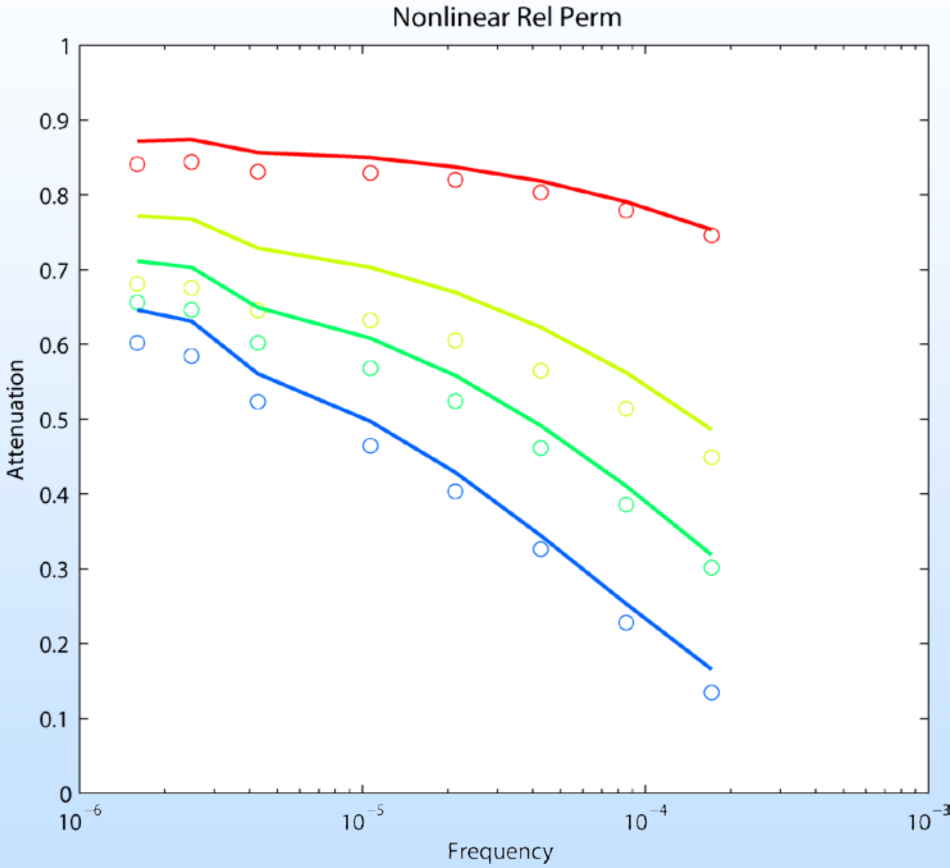


Permeability Effect



Relative Perm Effect





Accomplishments to Date

- Completed forward modeling tasks
- Completed manufacturing of the lab device
- Submitted abstracts to GHGT-12 and AGU
- A manuscript under preparation

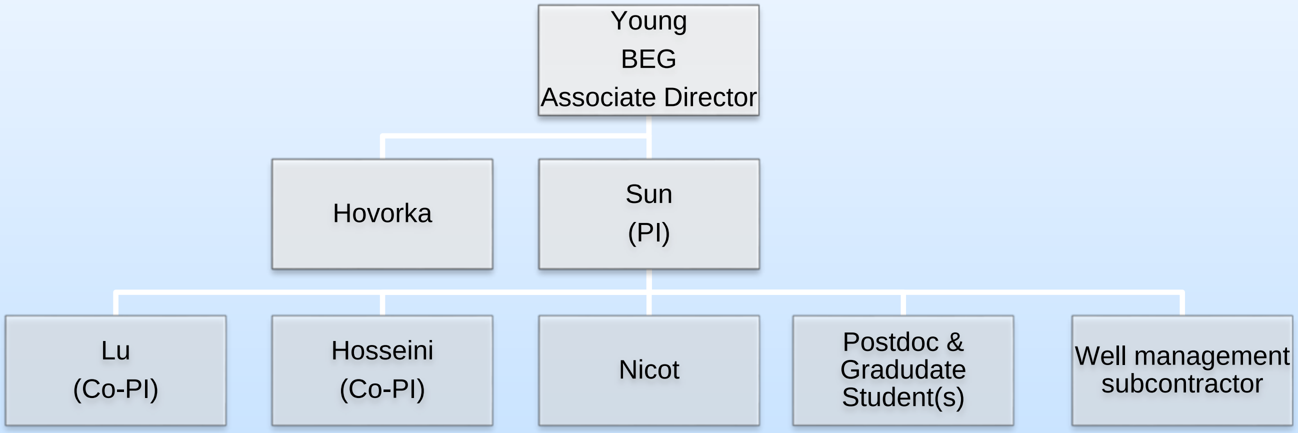
Summary

- Year 1 focused on forward modeling
- Results show that HPT is promising for leak detection
- Future plan: field and lab testing in Year 2

Appendix

Organization Chart

Bureau of Economic Geology, UT Austin
Gulf Coast Carbon Center



Gantt Chart

(Phase I ; Phase II)

Task	Description	Year 1				Year 2				Year 3			
		1	2	3	4	1	2	3	4	1	2	3	4
1	Update project management plan												
2	Modeling of harmonic pulse tests		1										
3	Lab experiment												
3.1	Experiment design and assembling				2								
3.2	Single-phase experiment												
3.3	Multiphase experiment								5				
4	Algorithm development												
4.1	Inversion technique												
4.2	Data assimilation										6		
5	Field demonstration												
5.1	Field site selection												
5.2	Site access & NEPA determination												
5.3	Field experiments					3		4					
6	Synthesis of results												
6.1	Tool user interface development												
6.2	Technology transfer												

Bibliography

N/A