Pressure-Based Inversion and Data Assimilation System (PIDAS) for CO_2 Monitoring

Project Number DE-FE0012231

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National Energy Technology Laboratory

Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting

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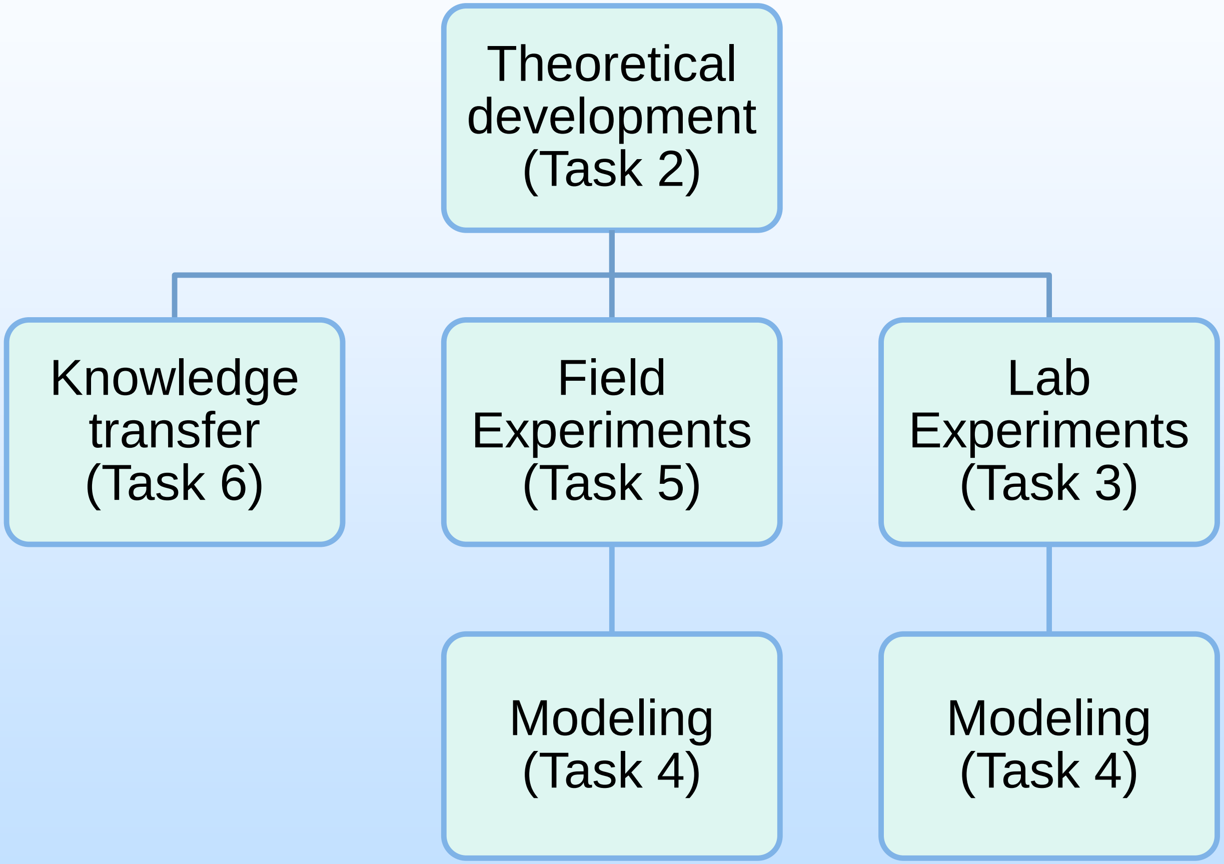
Presentation Outline

- Technical Status
- Accomplishments to Date
- Lessons Learned
- Synergy Opportunities
- Project Summary

Technical Status

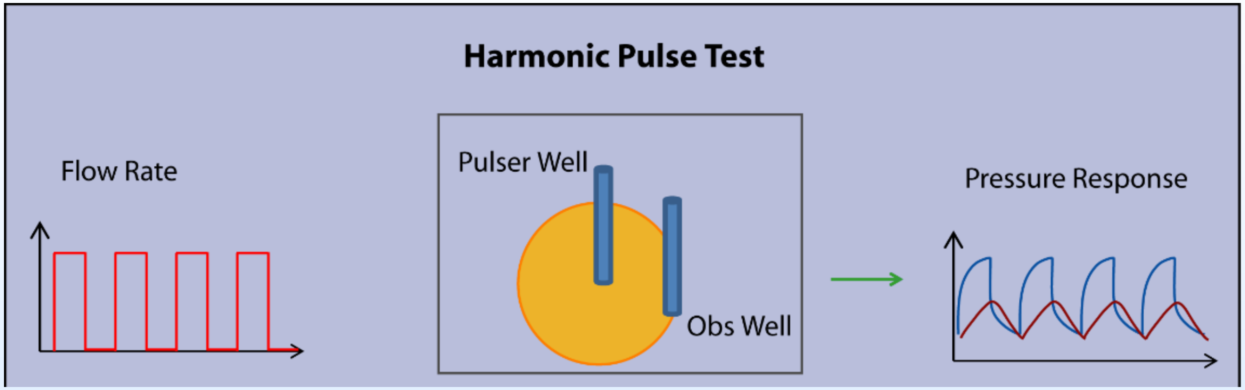
- Background
- Field experiment
- Lab experiment
- Numerical modeling

Project Overview



Harmonic Pulse Testing (HPT)

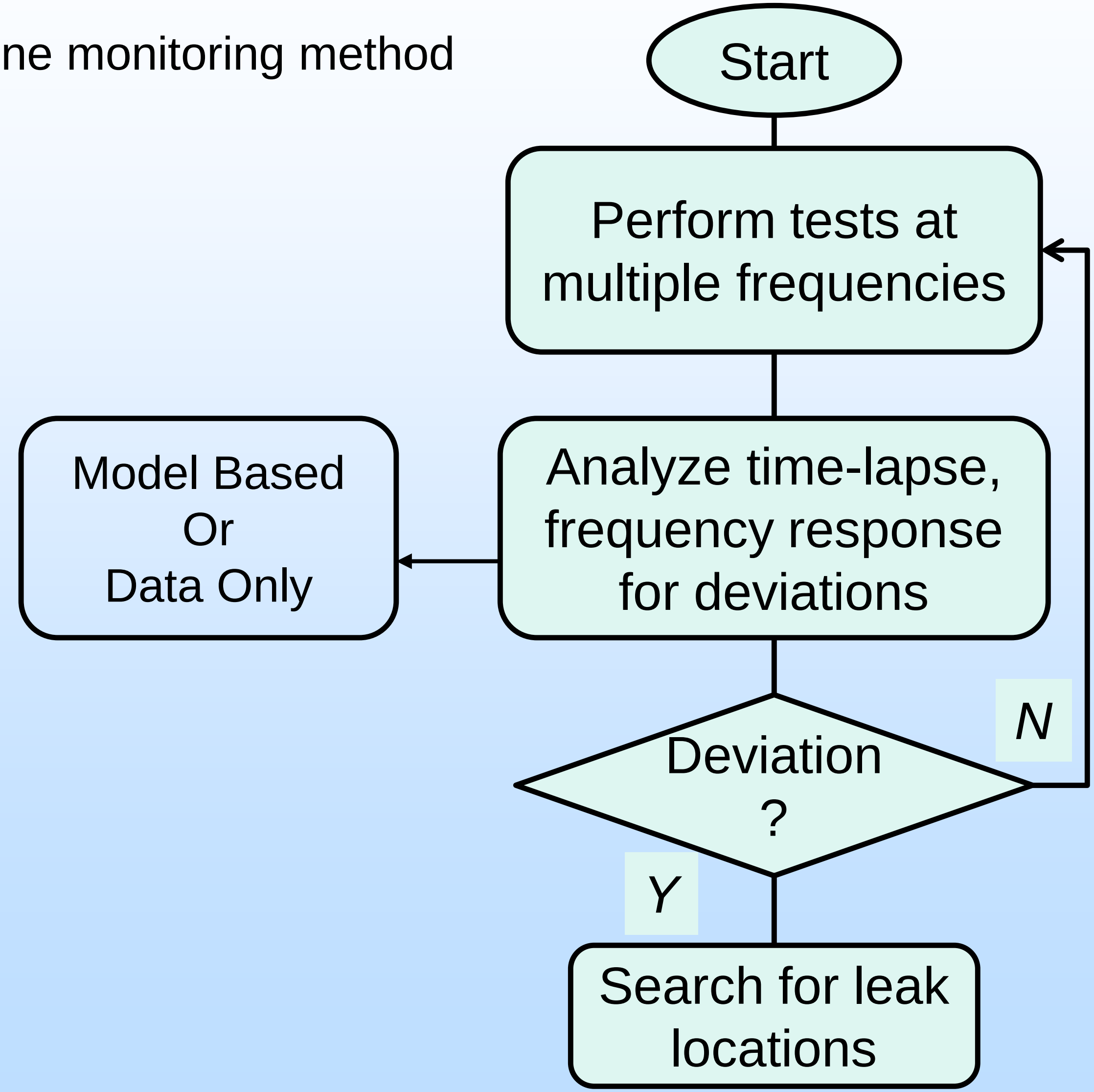
Coded injection pattern gives more information



- Has been used for reservoir characterization since 1960s
- Hypothesis: pulse testing as a leakage detection technology for CCS
- Expected advantages over other pressure-based methods
  - An active monitoring method: enhanced signal-to-noise ratio, thus mitigating reservoir noise interference
  - No net injection rate change: little interruptions to nominal reservoir operations

How Does It Work?

An in-zone monitoring method



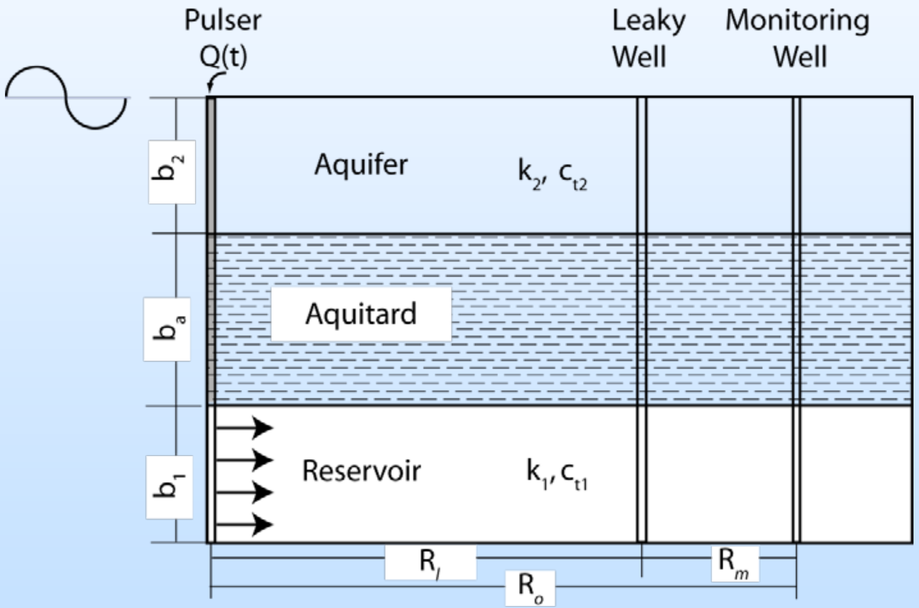
Frequency response function

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

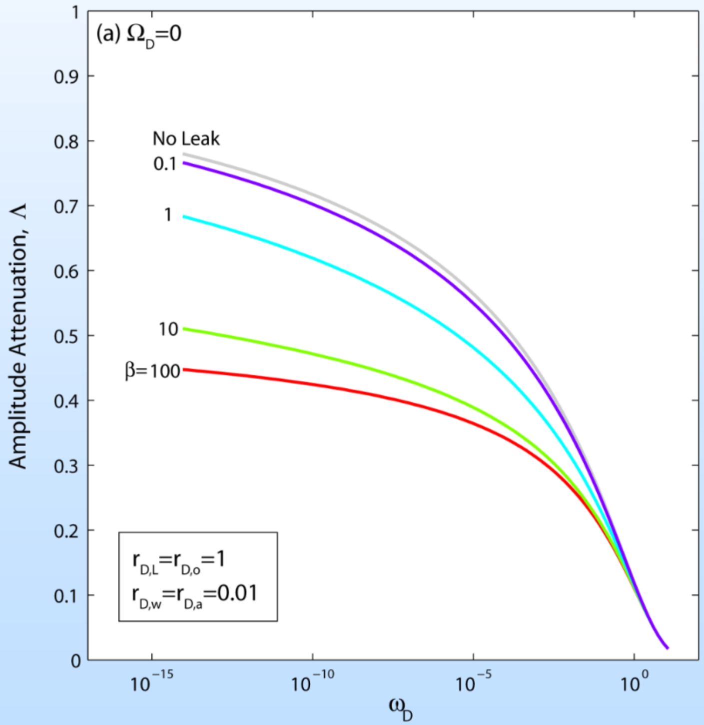
Task 2: Theoretical Development

Established the validity and feasibility of pulse testing

Problem setting



Amplitude response

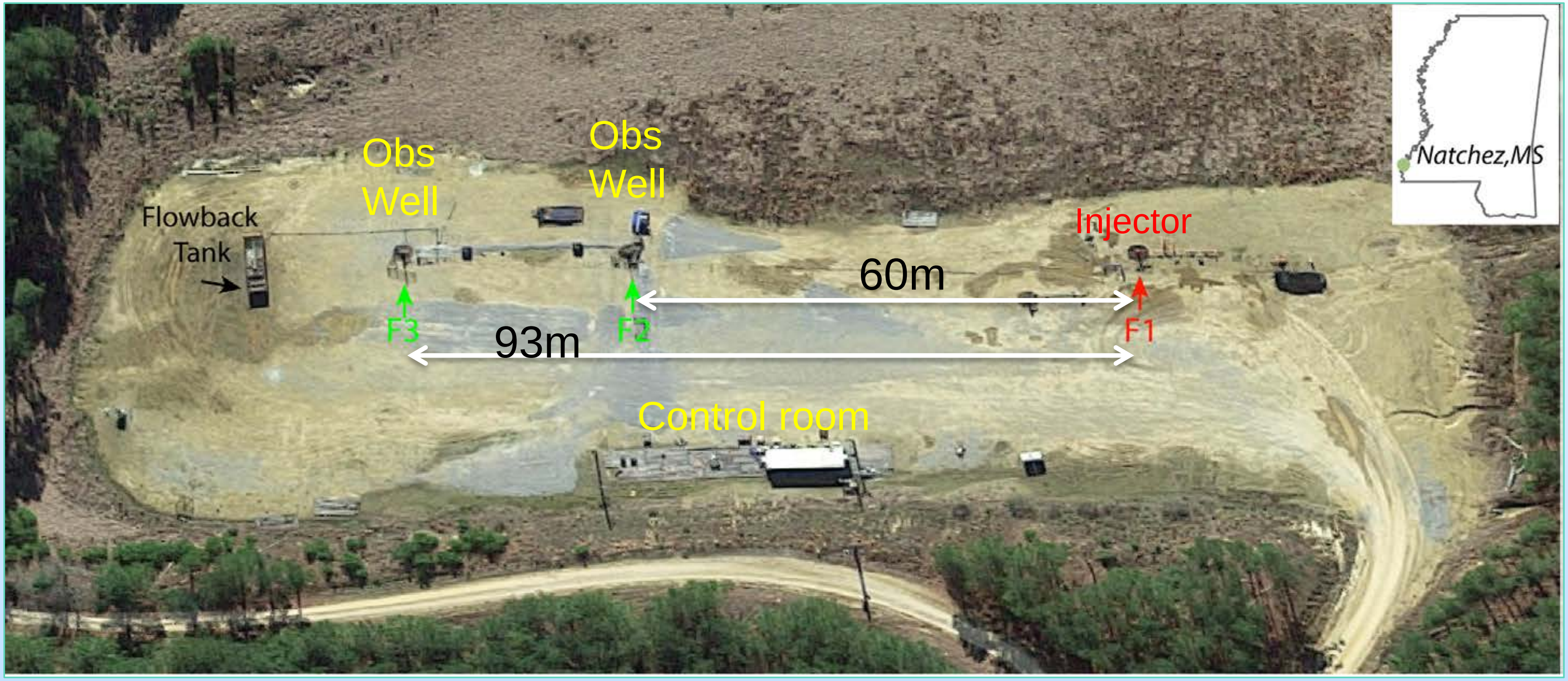


Ω = Resistance of leaky well to vertical flow

Sun et al., WRR, 2015

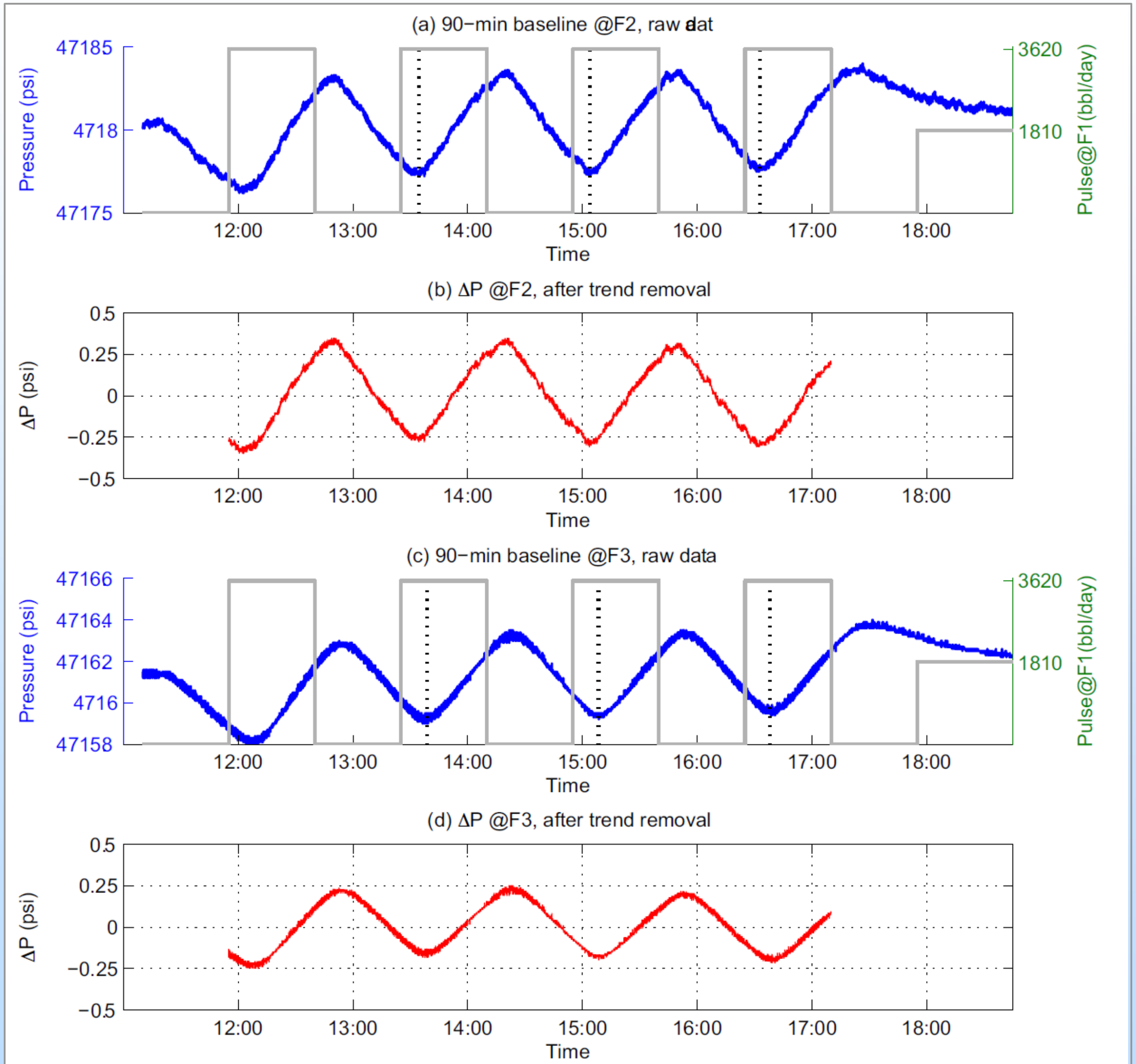
Task 5: Field Experiments

Validate the concept of pulse testing at field settings



Detailed Area of Study @ Cranfield, MS, January 19-31,2015

Baseline Experiment I



Pulsing Cycle 90min

Filtered Time Series

Reservoir temperature ~ 128.8 C
Gauge res: 0.01psi

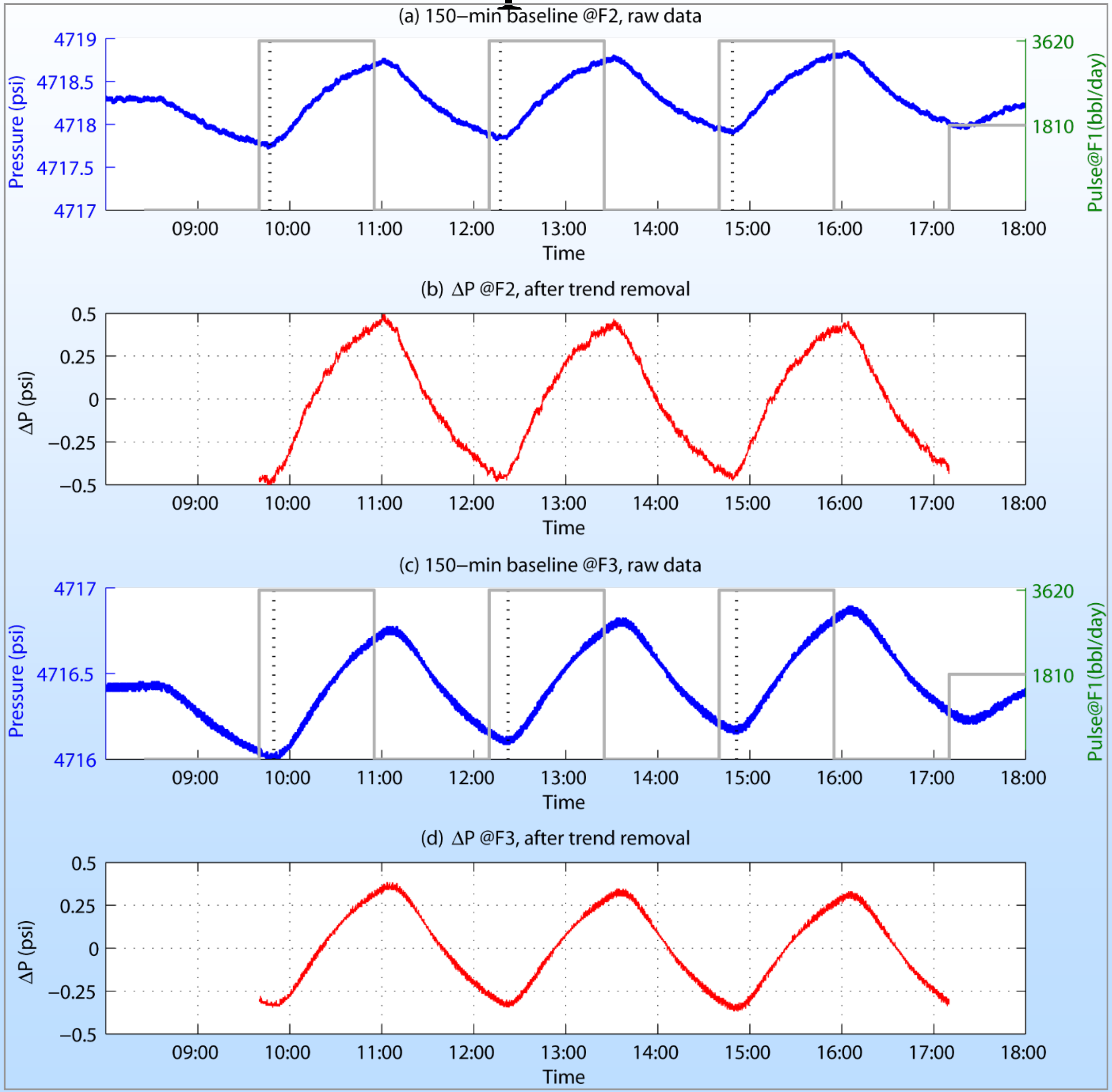
Filtered Time Series

Base Experiment II

Pulsing Cycle
T = 150min

Filtered
Time
Series

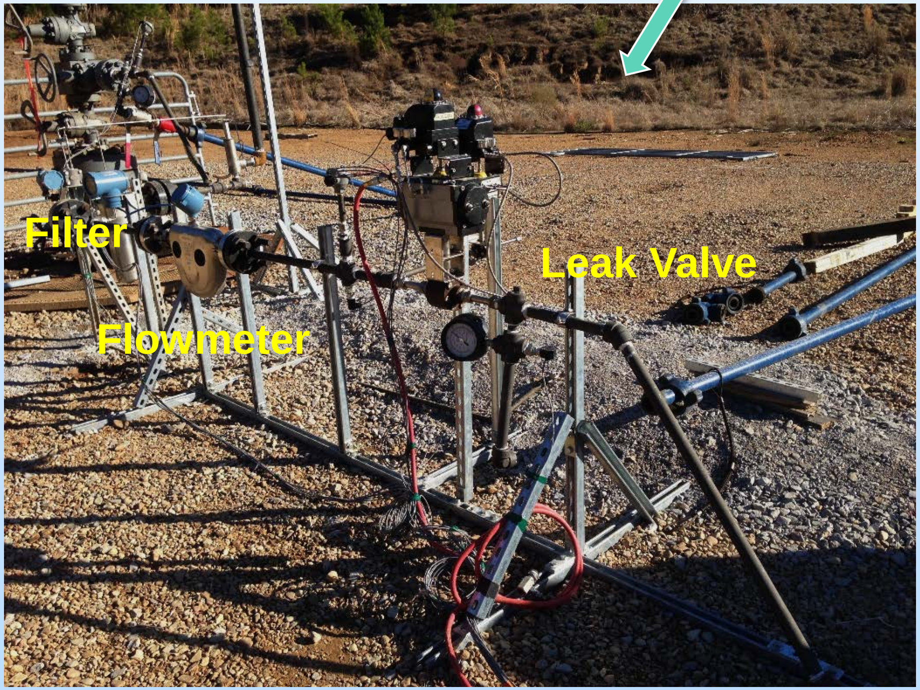
Filtered
Time
Series



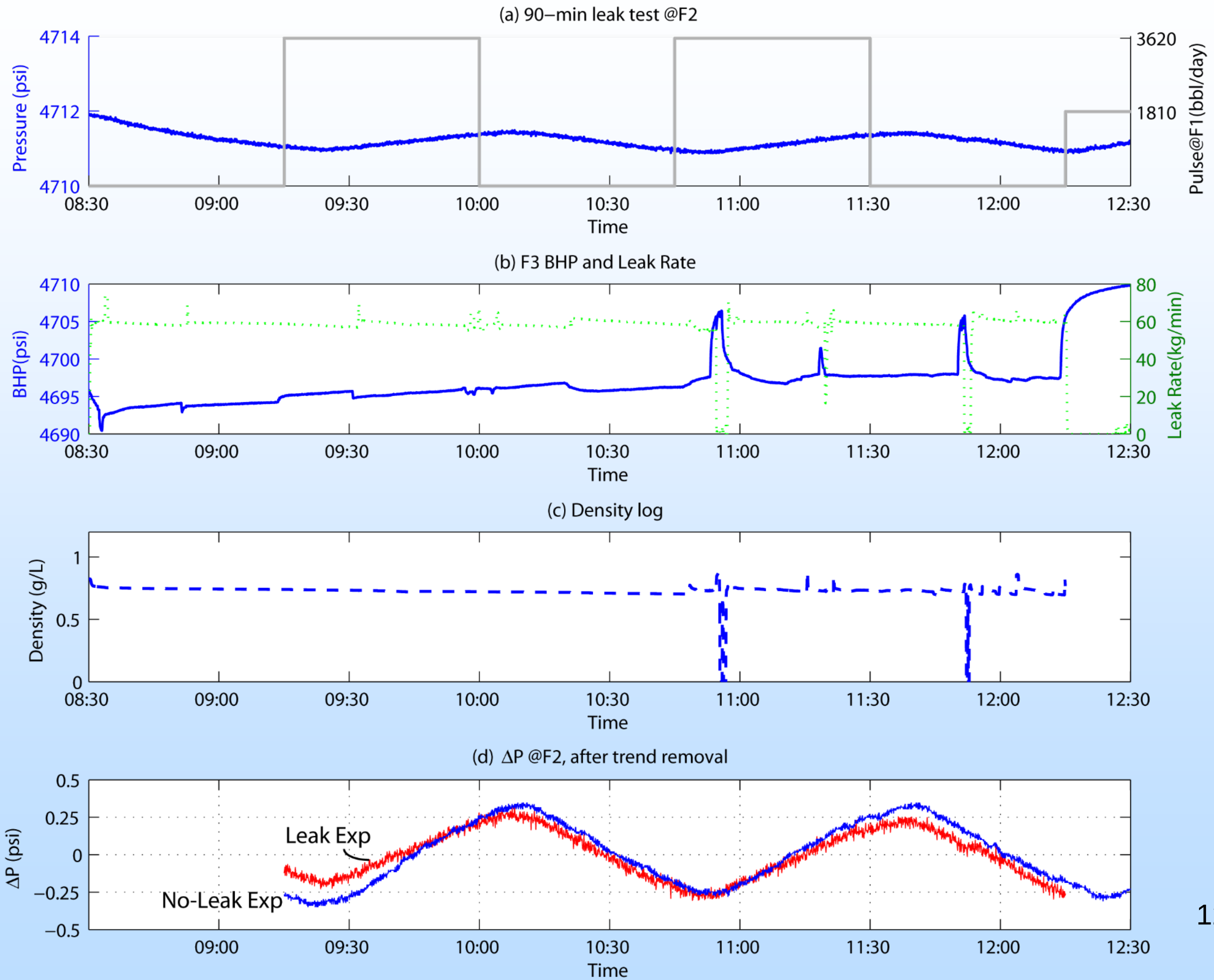
Leak Experiment Setup

Leak control infrastructure

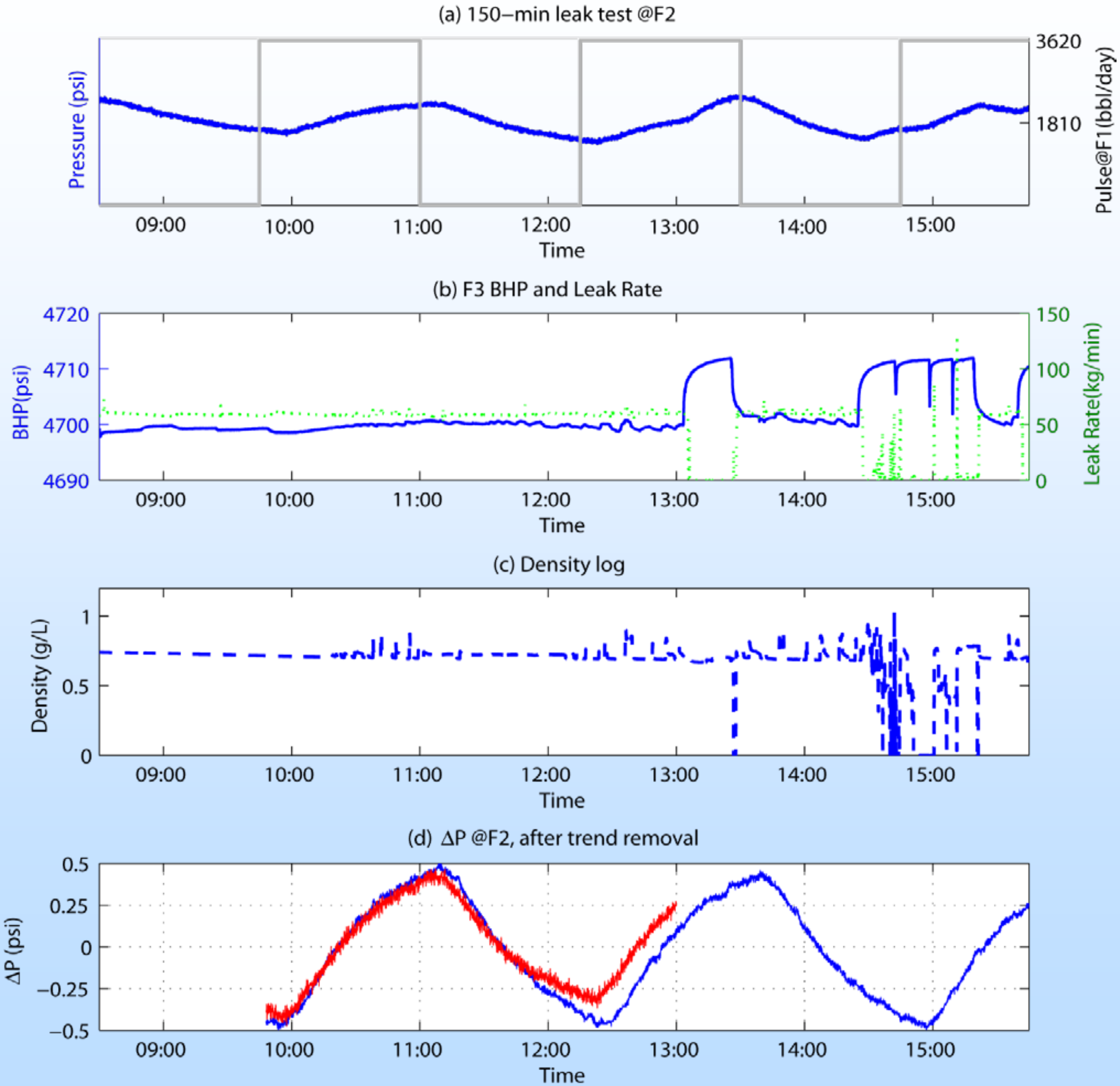
CFU31-F3



90-min, Leak Experiment

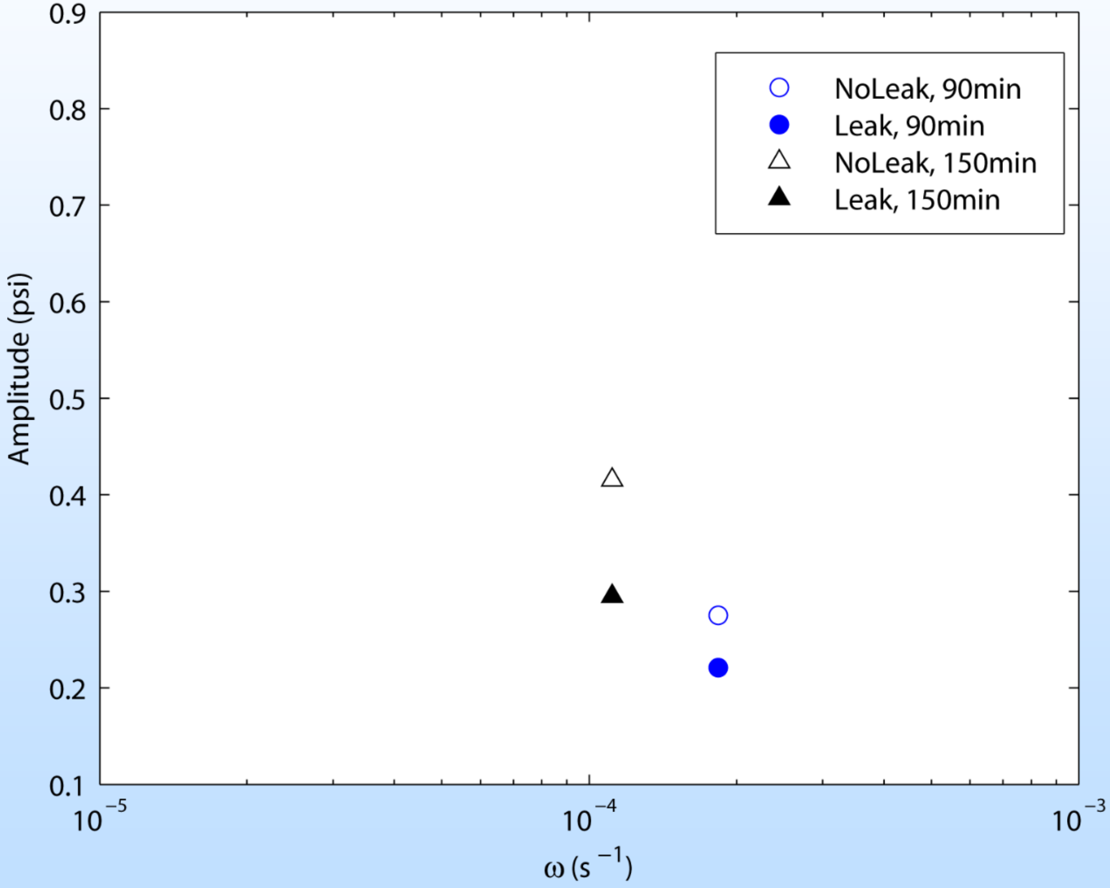


150-min, Leak Experiment



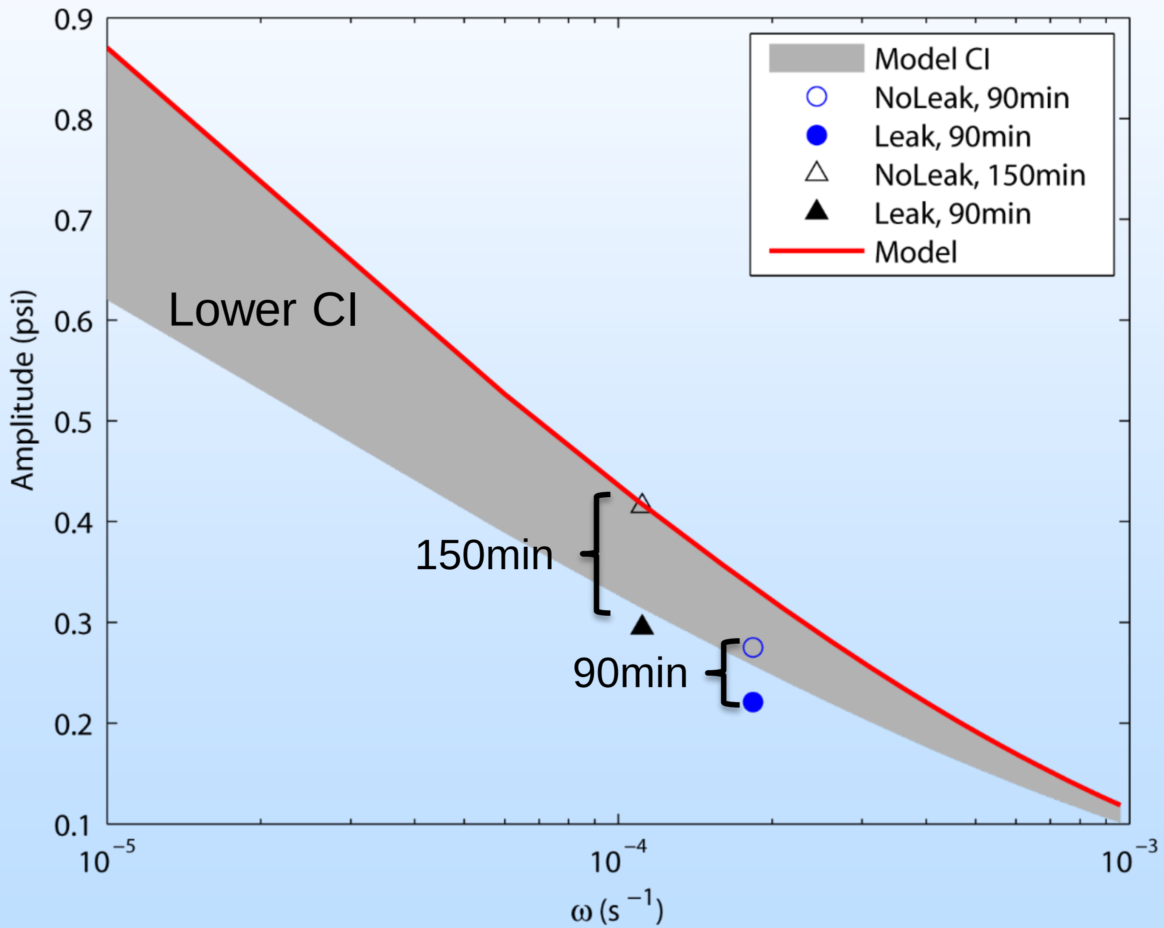
Frequency Domain Anomaly Detection

Amplitude vs. Frequency



Each experiment yields one data point on the plot

Frequency Domain Anomaly Detection

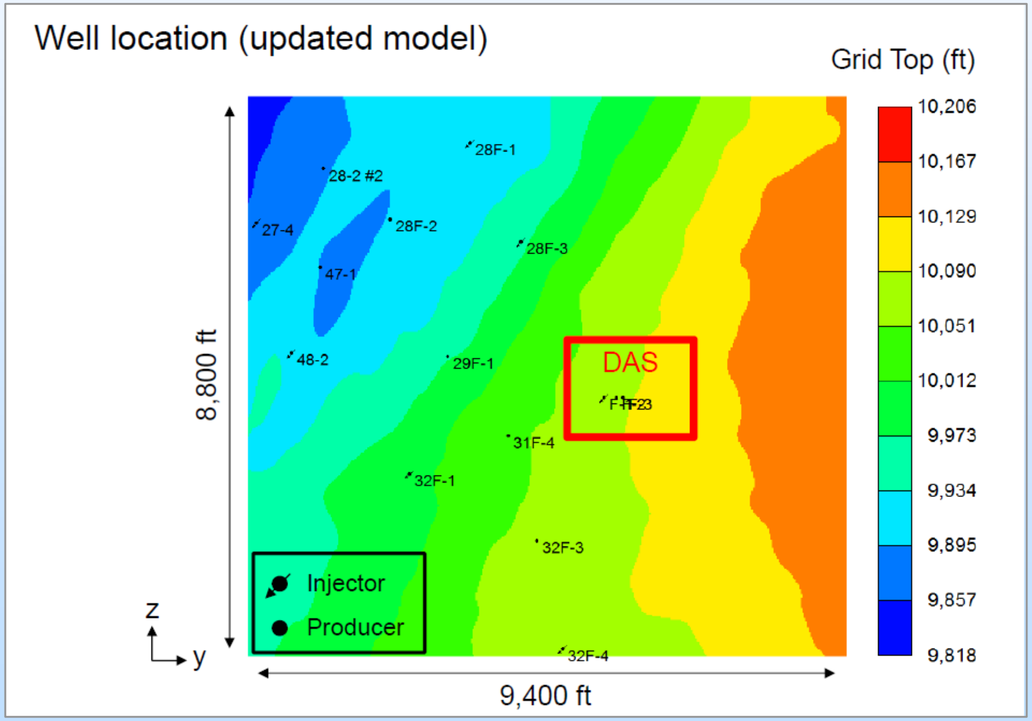


Sun et al., IJGGC, 2016

Task 4. 3D Modeling

- Can site-scale model reproduce the DAS pulse testing experiments?
  - Updated the existing model by including more wells
  - History matching
  - Refined mesh around DAS

UT IPARS (Integrated Parallel Accurate Reservoir Simulator) Simulation

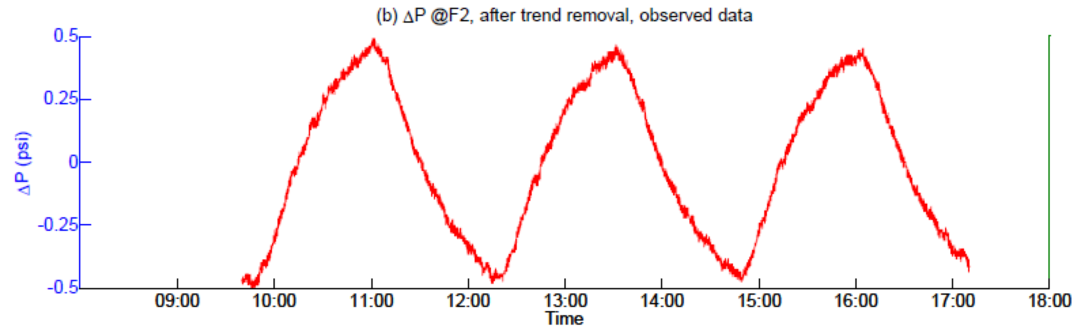


By Baehyun Min

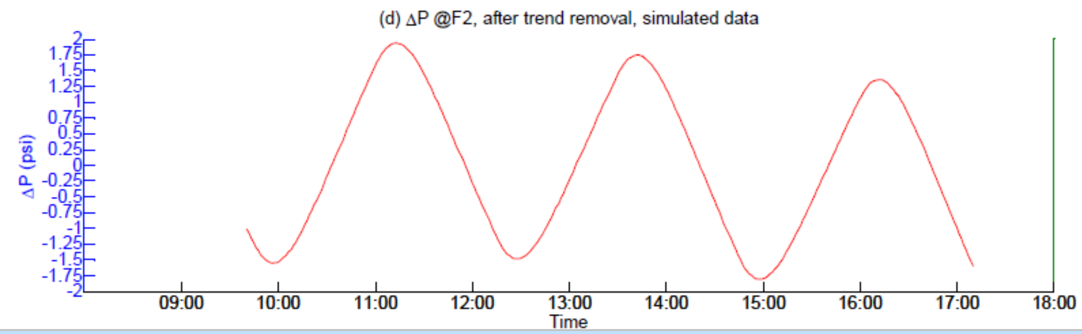
150-min Baseline Simulation

- Day 2 (Jan 20, 2015): BHP@F2: 150-min. experiment without leakage

❑ Observed



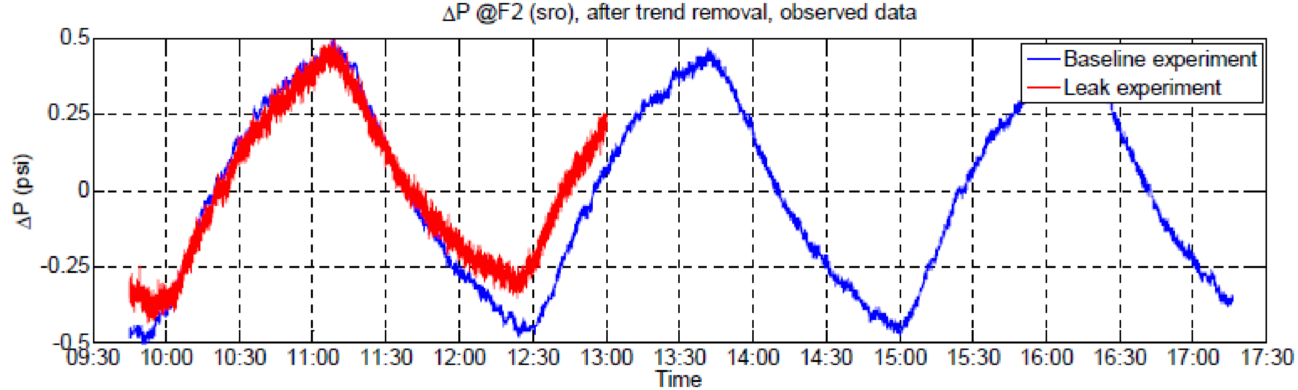
❑ Simulated



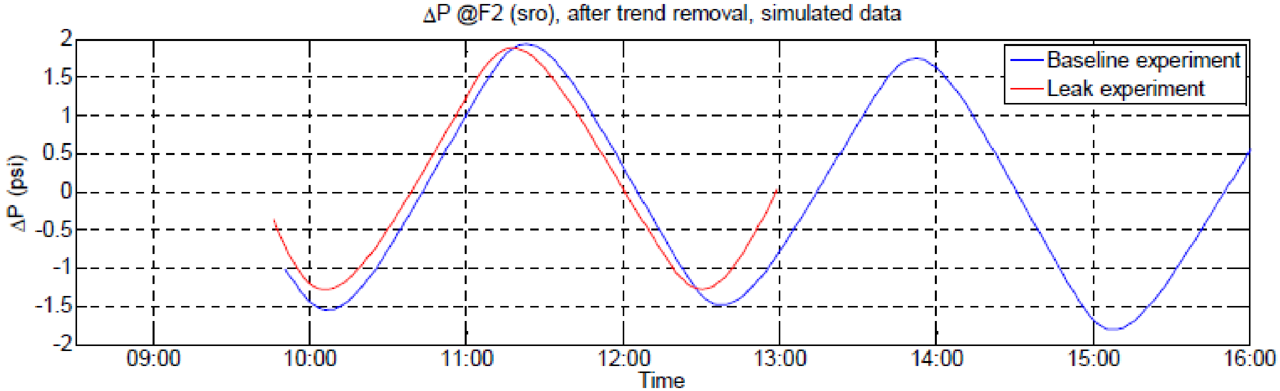
150-min Leak Simulation

- 150-min. experiment

❑ Observed

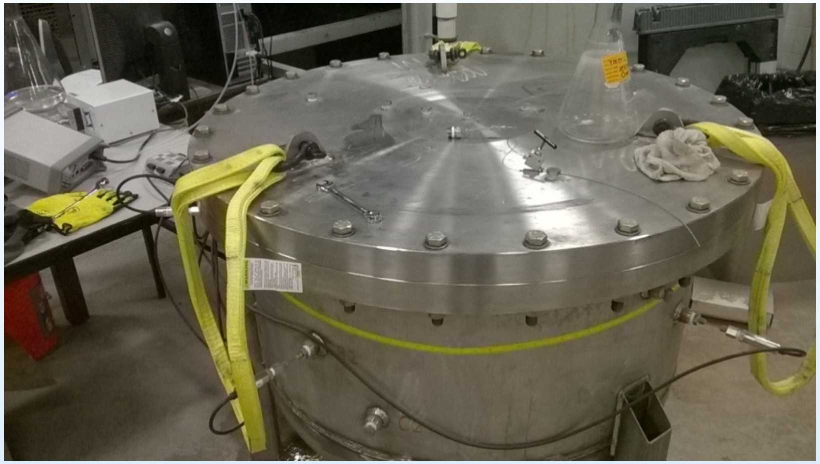


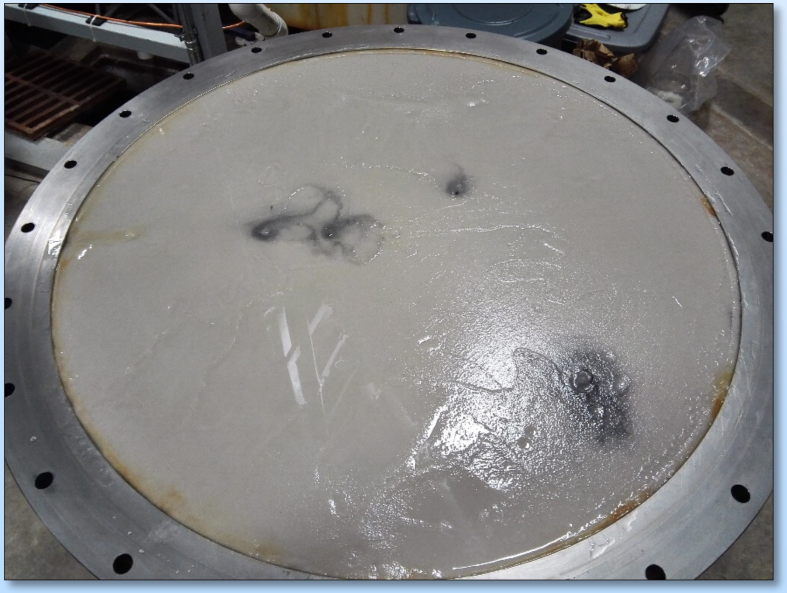
❑ Simulated

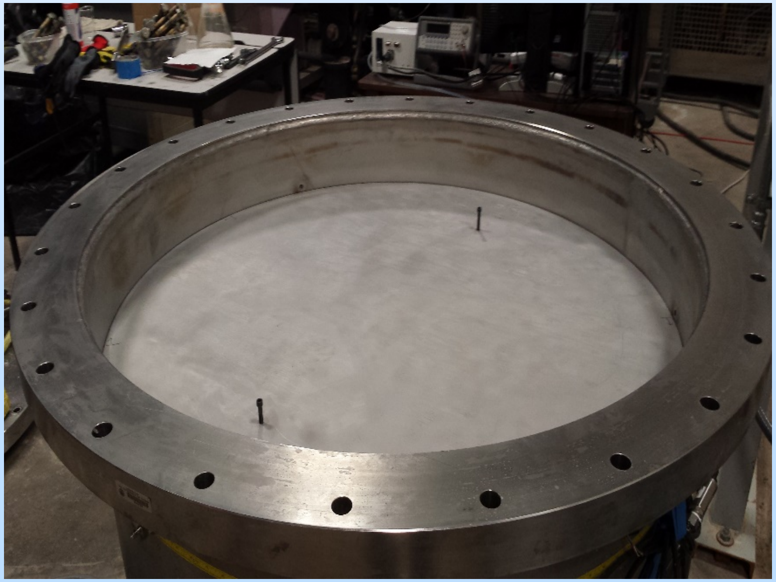


Task 3. Lab Experiments

1-m diameter, 0.75 m tall



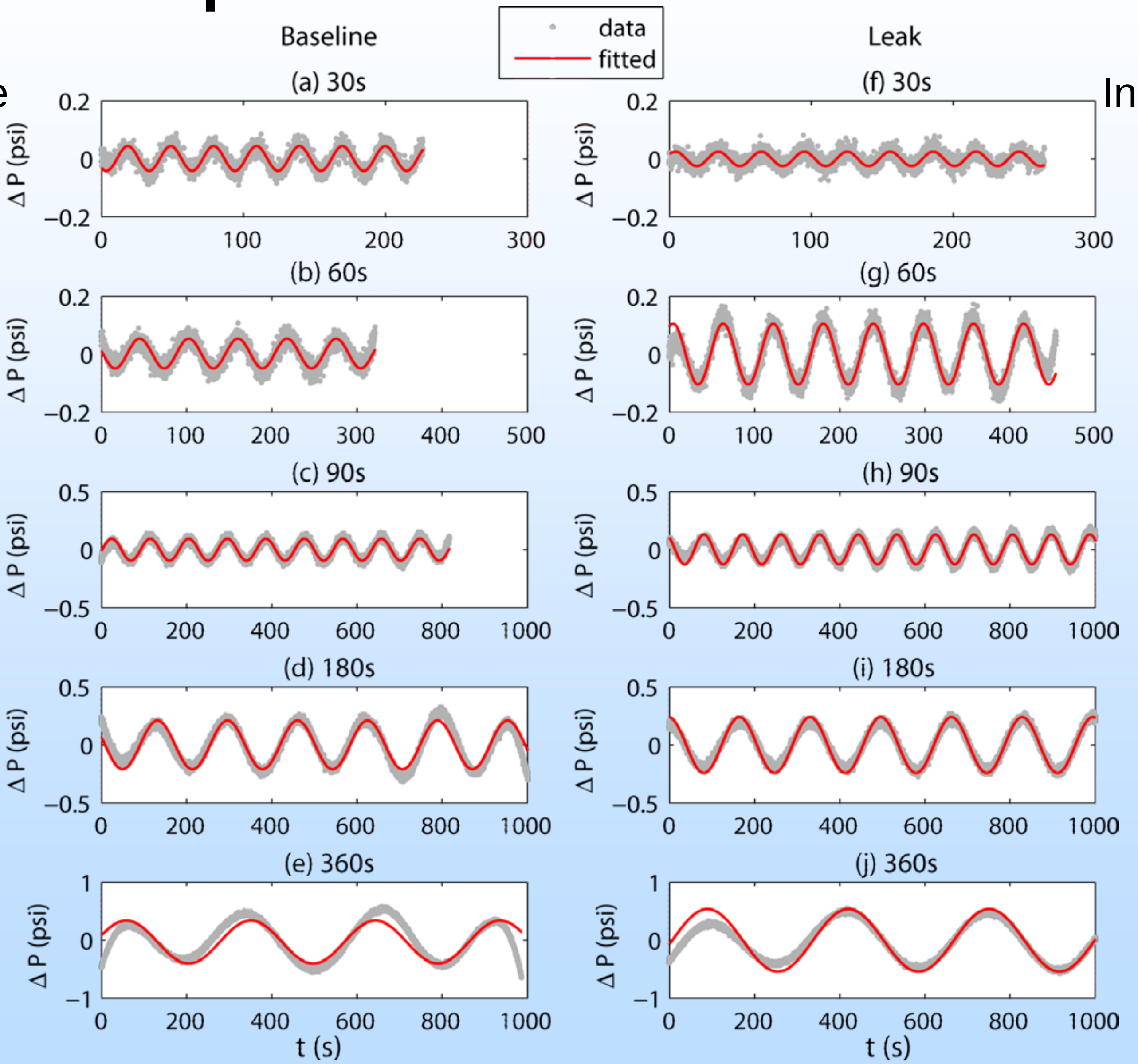




Experimental Results

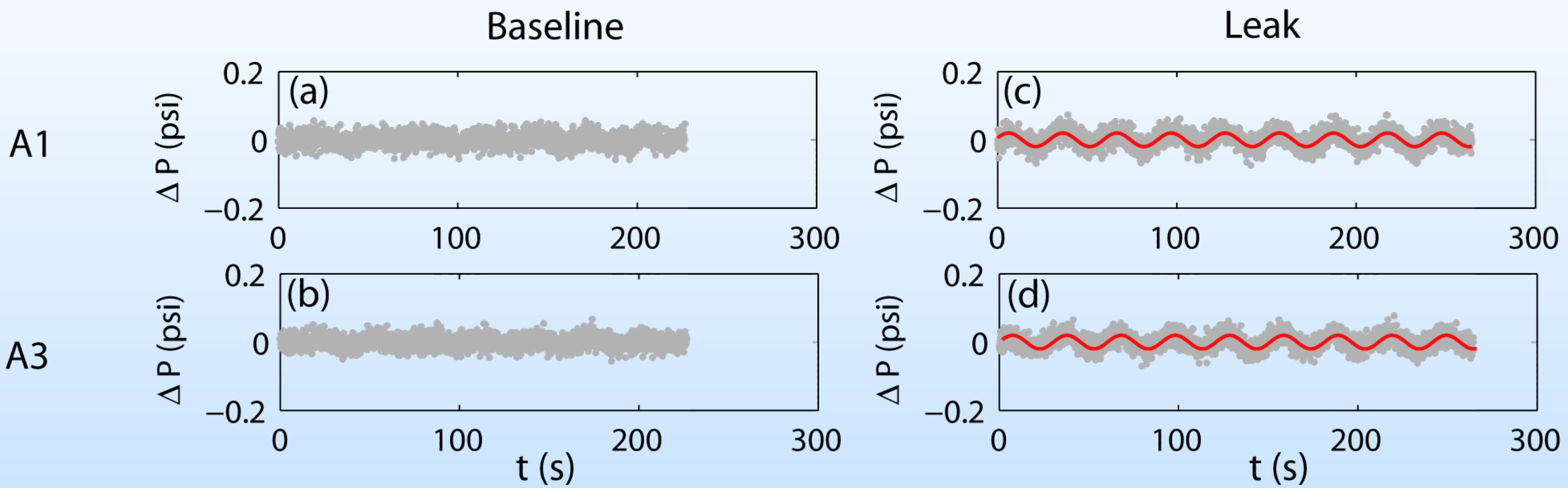
Single phase

In-zone sensor

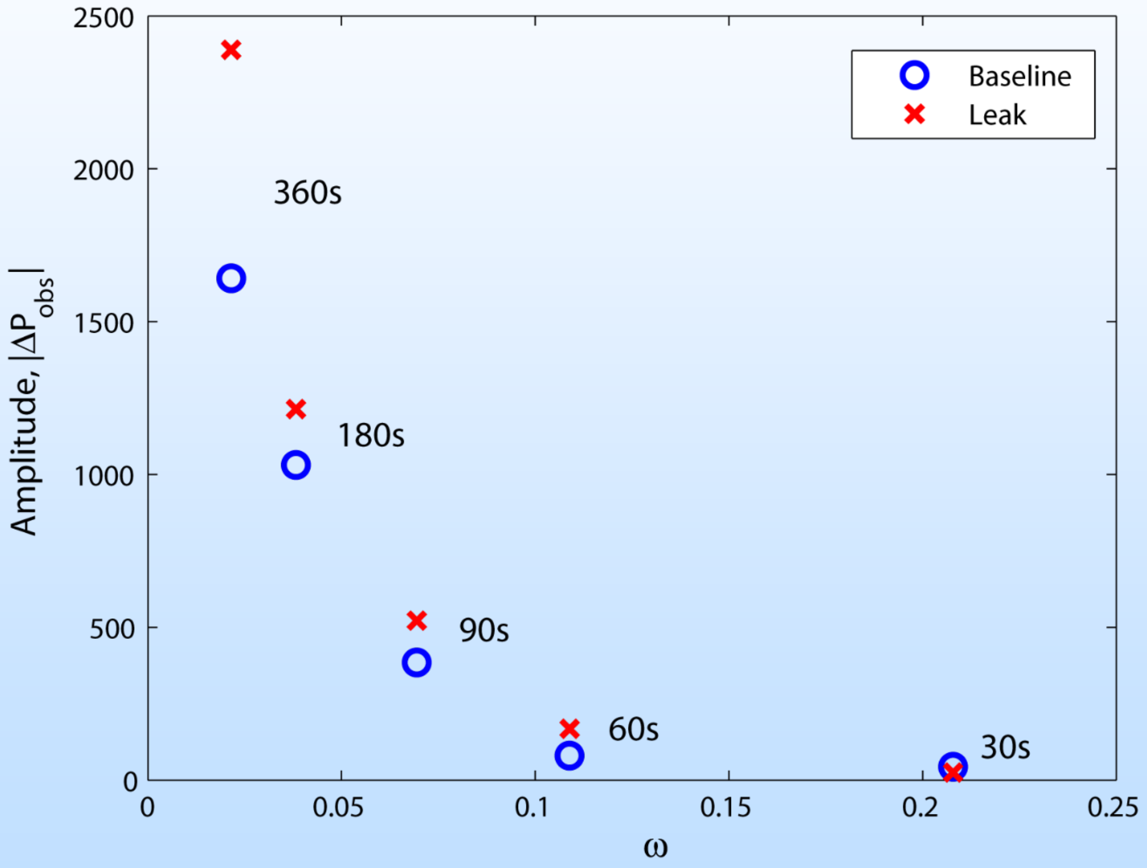


Experimental Results

Above zone sensor



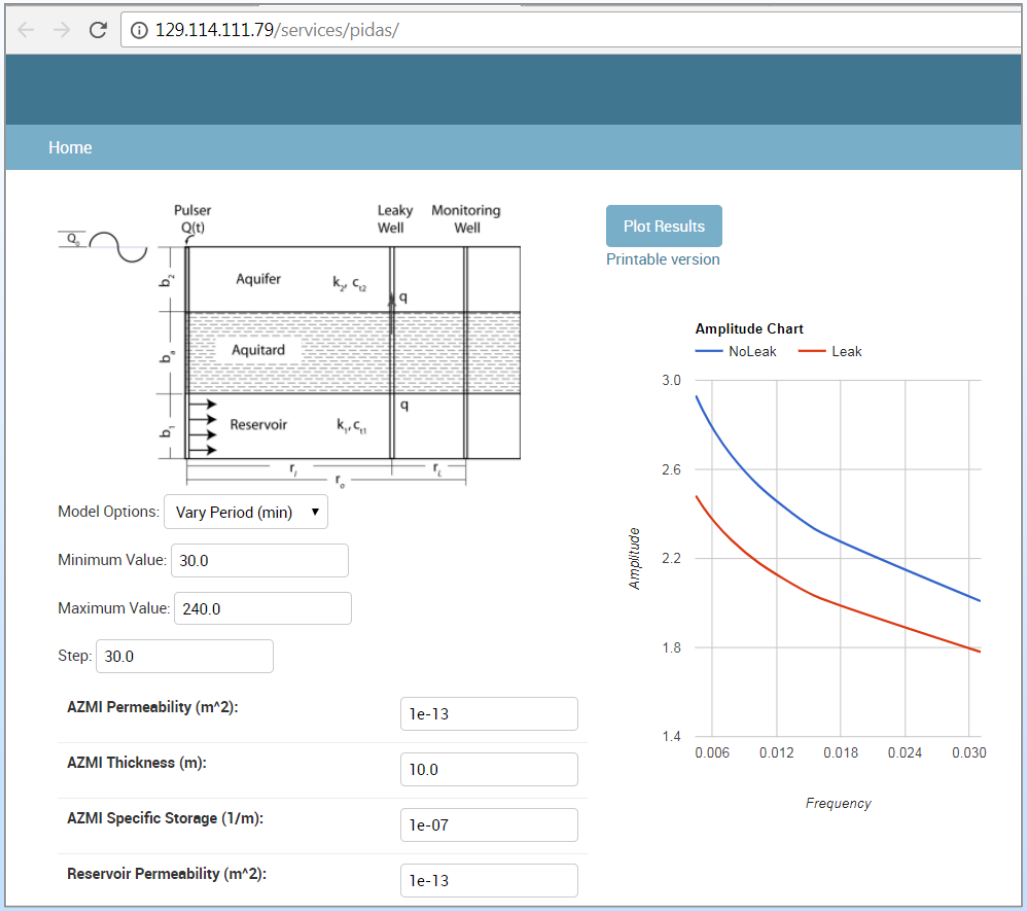
Frequency Domain Diagram



Sun et al., JoH, 2017

Task 6 Result Dissemination

- Developed web-based tool
- Documented results from each task in peer-reviewed journal papers



Accomplishments to Date

- Task 2: Theoretical and numerical analyses
  - Year 1: Established theoretical basis and validated the concept of pulse-testing-based leakage detection numerically
- Task 5: Field experiments
  - Year 2: Demonstrated viability of the pulse testing leakage detection technique in the field
- Task 3: Laboratory experiments
  - Year 1: Device manufacturing, experimental design, and single-phase experiments
  - Year 2&3: Additional validation experiments
- Task 4: Data assimilation algorithms
  - Year 2&3: Developing and testing algorithms
- Task 6: Result dissemination

Lessons Learned

– Performing pulse testing under controlled conditions is more challenging than it sounds to be
– Wellbore flow may require coupling with special well flow modules
– Data-driven models may be easier to apply
– Make sense to optimize frequency and rate of pulse testing

Synergy Opportunities

- Any injection history may be considered
- Web-based toolbox for scoping analysis

Project Summary

- Leaks will modify the system frequency response function and can be detected if an appropriate pulsing period is used
- Longer HPT pulsing periods increase coverage area
- Lower reservoir permeability or, equivalently, higher upper aquifer permeability, favors detection of leakage, if all other parameters are fixed
- The amplitude and phase of frequency response function provide independent information regarding the current system status and can be combined to locate leaky well locations

Acknowledgements

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  - Center for Subsurface Modeling: Mary Wheeler, Baehyun Min

- LBNL: Barry Freifeld, Paul Cook

- Sandia Technologies LLC: Kirk Delaune

Appendix

– These slides will not be discussed during the presentation, but are mandatory.

Benefit to the Program

- Carbon program goal being addressed

Develop and validate technologies to ensure 99 percent storage permanence

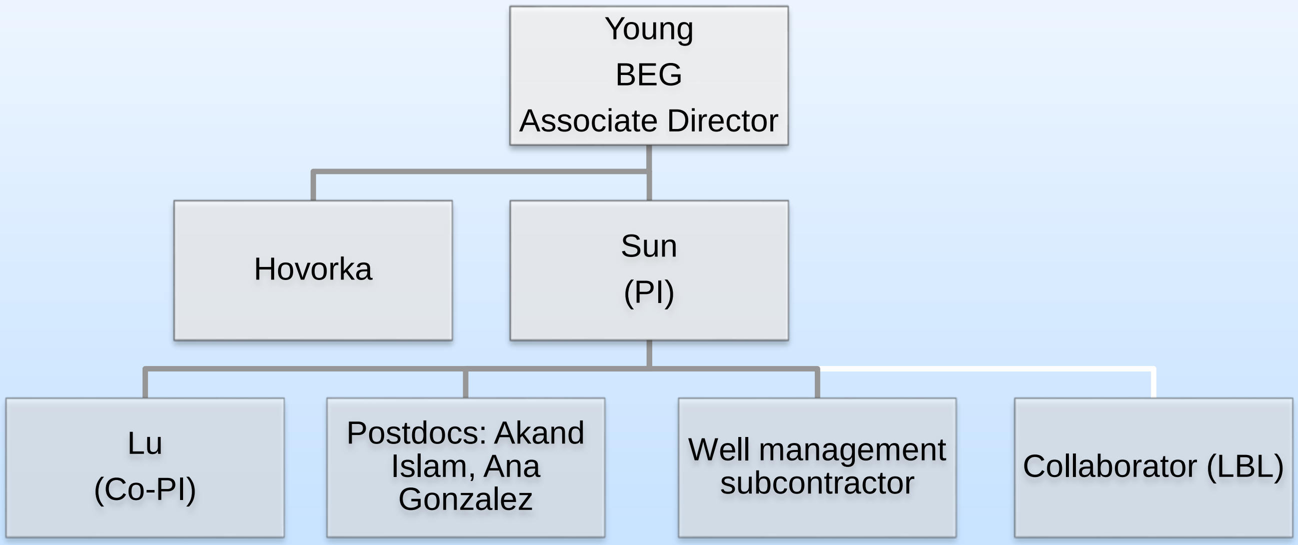
- Project benefits
  - The PIDAS project develops and demonstrates a pressure-based, pulse testing technology for leakage detection in carbon storage reservoirs.
  - Active monitoring strategy for improving signal-to-noise ratio for injection zone monitoring

Project Overview
Goals and Objectives

- Demonstrate the utility of pulse testing for leakage detection
- Develop relevant data analyses and inversion methodologies
- Provide an experimental design tool for CCS operators to apply the technology

Organization Chart

Bureau of Economic Geology, UT Austin
Gulf Coast Carbon Center



Gantt Chart

Table 2. Project Gantt chart
(Numbers in table rows indicate milestones).
(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												

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3. Sun, A. Y., J. Lu, B. Freifeld, S. Hovorka, and A. W. Islam, 2016, Using pulse testing for leakage detection in carbon storage reservoirs: A field demonstration. International Journal of Greenhouse Gas Control, 46, 215-227.
4. Sun, A. Y., M. F. Wheeler, and A. W. Islam, 2017, Identifying attributes of CO2 leakage zones in shallow aquifers using a parametric level set method. Greenhouse Gases: Science and Technology.
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6. Min, B., A. Y. Sun, M.F. Wheeler, Parallel multiobjective optimization for the coupled compositional/geomechanical modeling of pulse testing, revised for SPE Journal.