SPARSE

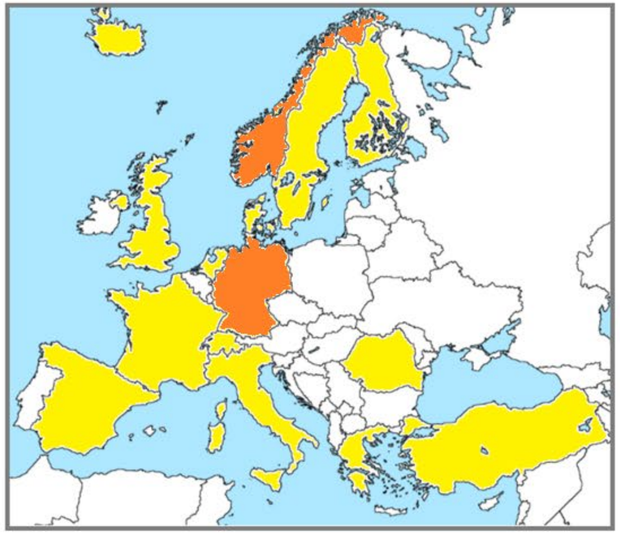
ACT4 SPARSE
EM Modeling and Data Acquisition

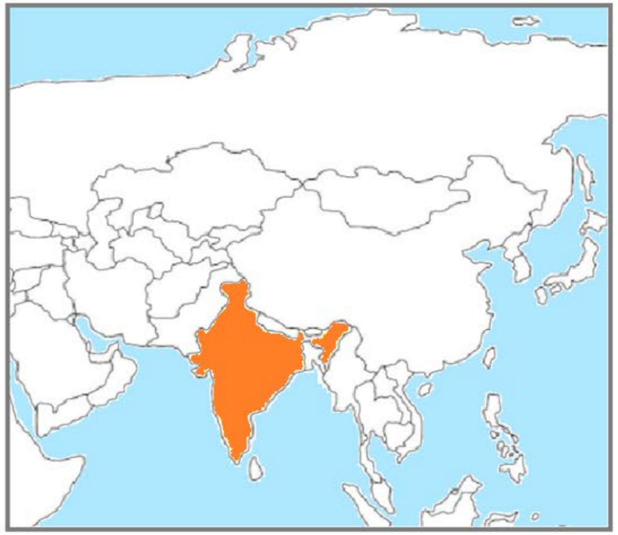
Teknologi for et bedre samfunn

SINTEF

This is ACT (now CETP)

Funding agencies from 16 countries, regions, and provinces are collaborating on calls and knowledge sharing within CCUS





- **Alberta (Canada)**
- **USA**

- Denmark
- France
- Germany
- Greece
- Italy

- The Netherlands
- **Norway**
- Nordic countries
- Romania

- Spain
- Switzerland
- Turkey
- UK

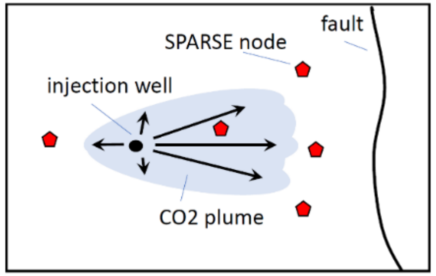
- India

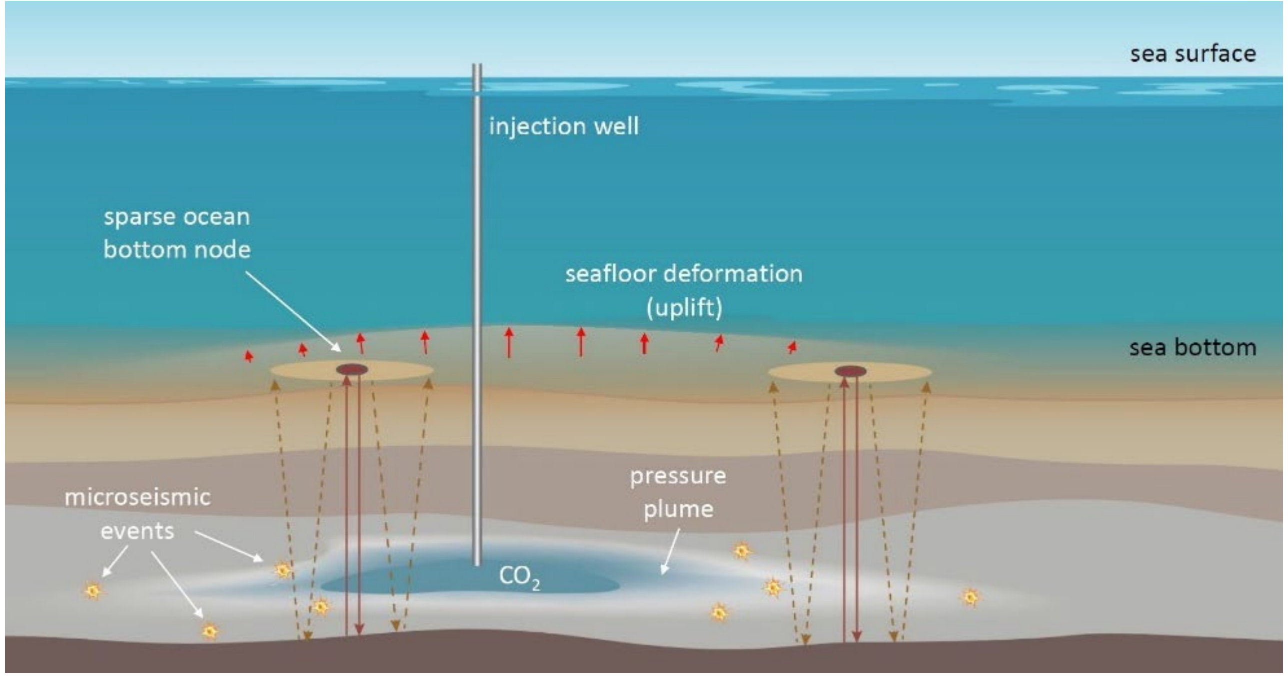
www.act-ccs.eu

ACT4 SPARSE:

Sparse Passive-Active Reservoir monitoring using Seismic, Electromagnetics, gravity, and surface deformation

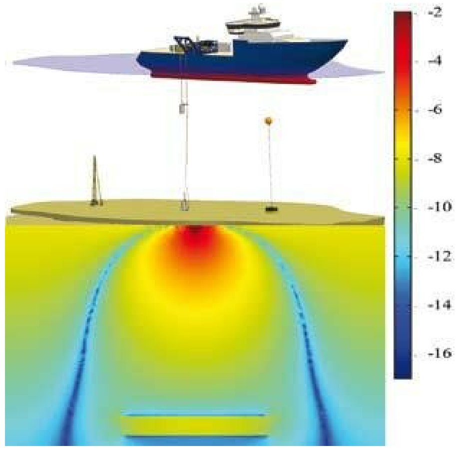
- Enable low-cost long-term monitoring & facilitate GT storage
- SPARSE background monitoring
  - Node-based conformance and containment monitoring
    - Sparse data, sparse nodes
    - May trigger target-oriented active surveys when needed
    - Reduce / remove need for conventional active surveys
- Main requirements:
  - Extract sufficient information from sparse data for detection and quantification
  - Track pressure, saturation, stress and strain changes
  - High repeatability
  - Low-cost installation, operation, maintenance over decades
  - Solutions must be practical

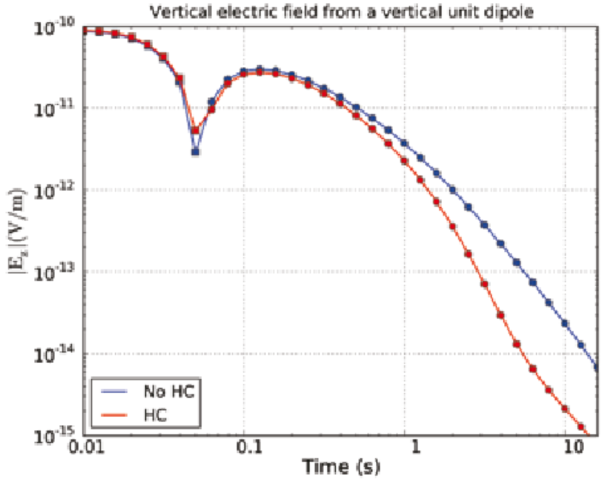


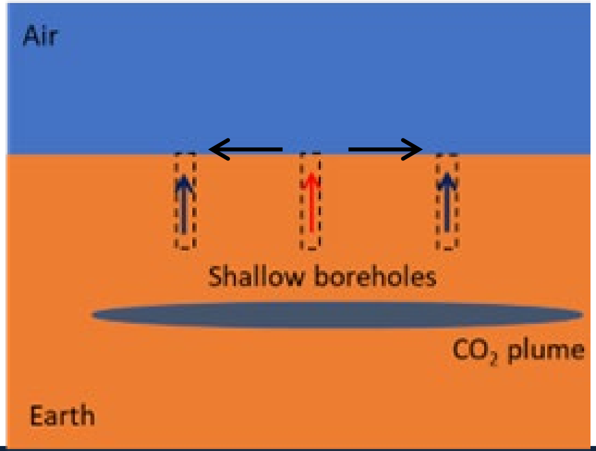


LBNL Research Topic #1

Numerical Modeling, Implementation, Testing, and Data Processing for Optimized Land-Vertical Source (VS) CSEM measurement





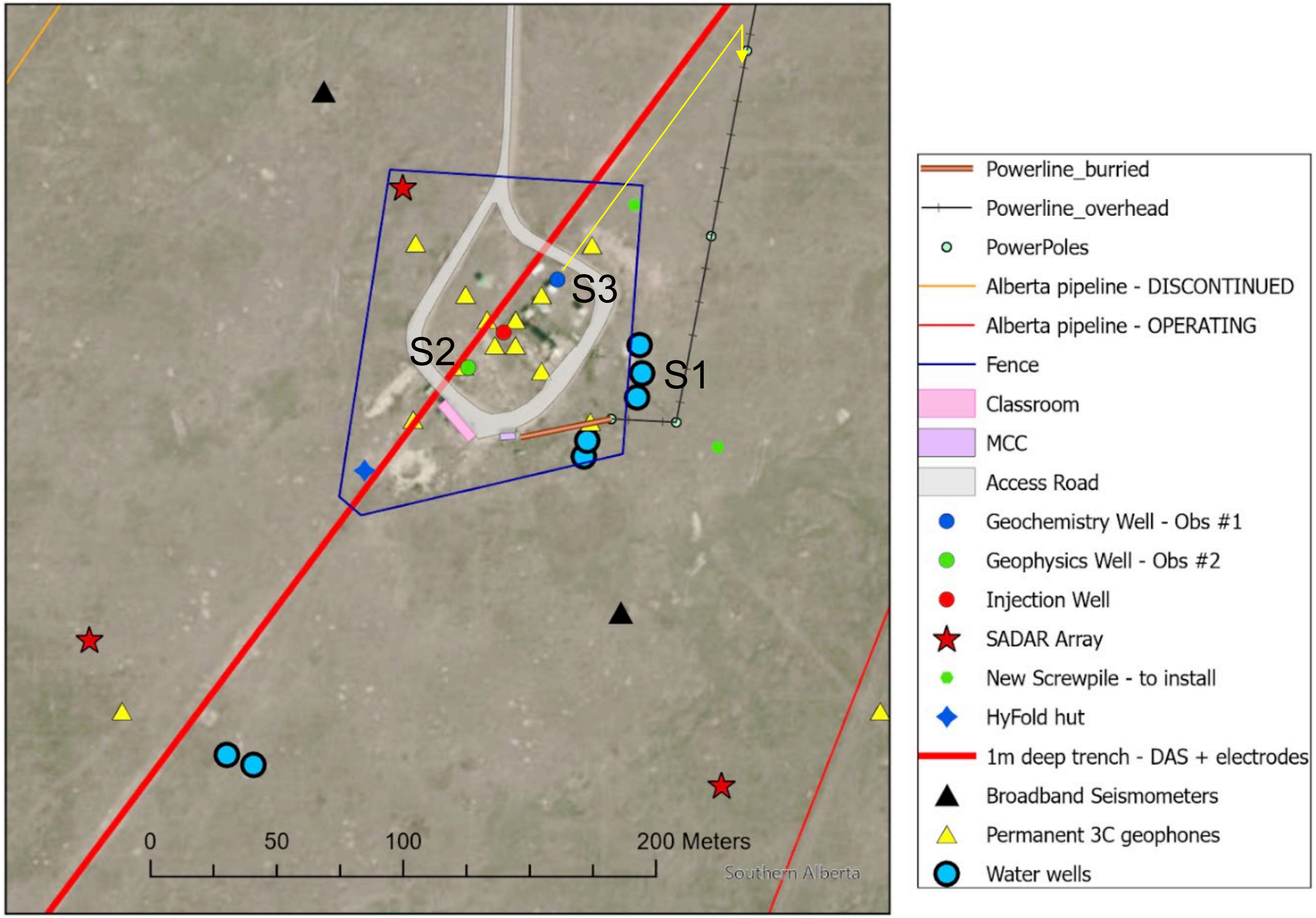


Associated Project Work Packages and Tasks

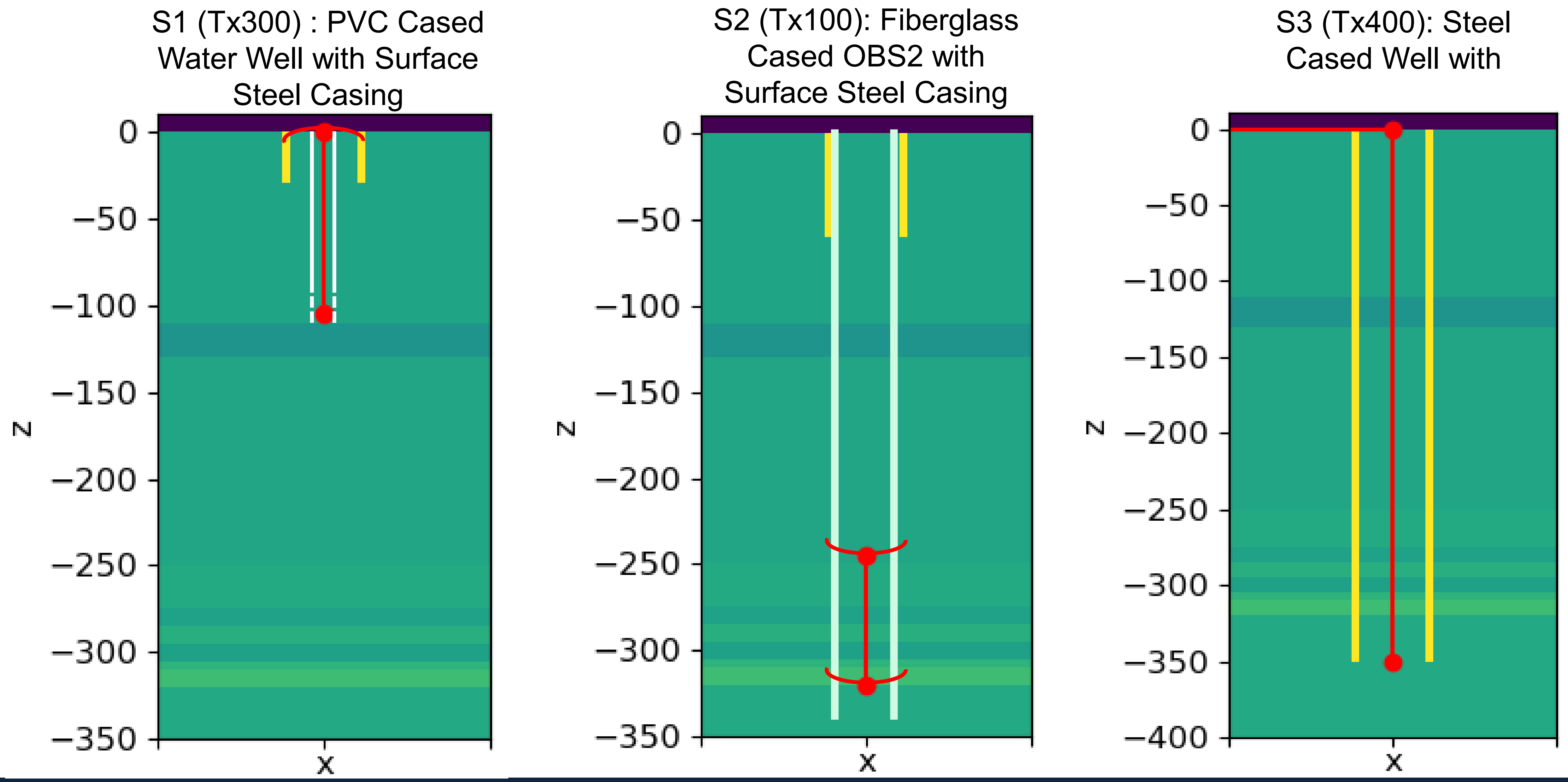
- WP2 : Sparse Geophysical Monitoring and Quantification
  - Tasks
    - Task 2.1 Sparse Geophysical Monitoring
    - Task 2.2 Data Exploitation
  - Milestones and Deliverables
    - M2.1, D 2.1 - Report /paper describing CSEM modeling study for CaMI Site
- WP4 : Node Design and Implementation (LBNL)
  - Tasks
    - **Task 4.1 Optimum Design**
    - **Task 4.2 Technical Realization**
    - Task 4.3 Automatic Data Processing, Reduction and Evaluation
  - Milestones and Deliverables
    - M4.1, D4.1 – Report describing optimized vertical source VS CSEM system
    - M4.2, D4.2 - Report on deployment of VS CSEM System at CaMI and first data acquisition
    - M4.3, D4.3 - Report on first year of quarterly VS CSEM data acquisition
    - M4.4, D4.4 - Report on first year of quarterly VSD CSEM data acquisition
    - D4.5 – Guidelines/paper for Implementation of SPARSE Monitoring (with SINTEF)

EM Modeling and Measurements at CaMI

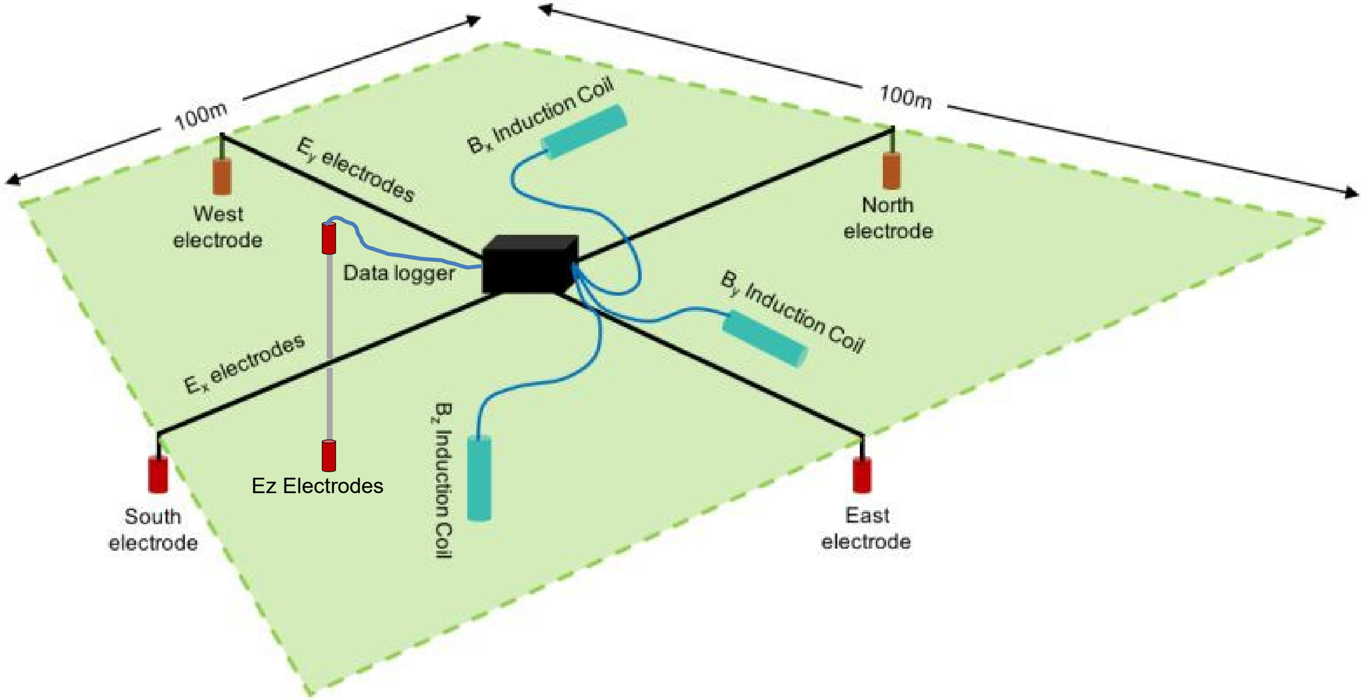
- S1 – Shallow VED in water well
- S2 – Deep VED using ERT array on OBS2
- S3 – Energize Steel casing of OBS1



Well / Source Construction



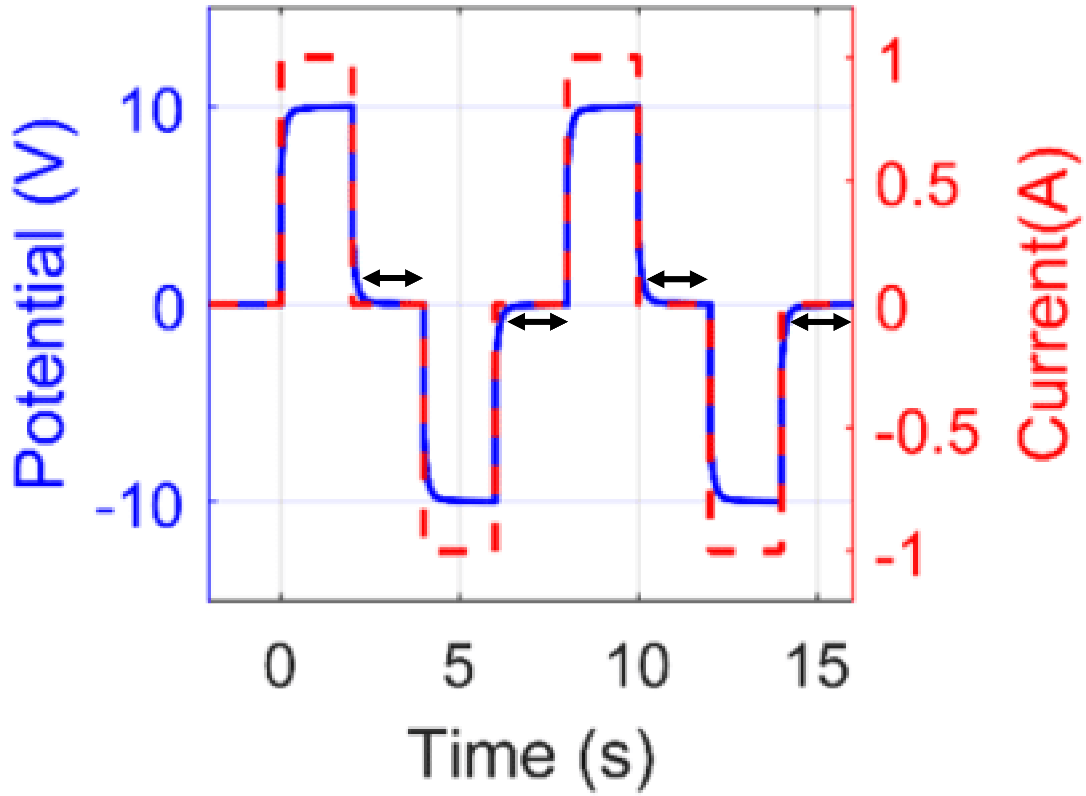
EM Nodal Receivers



Time Domain vs Frequency Domain

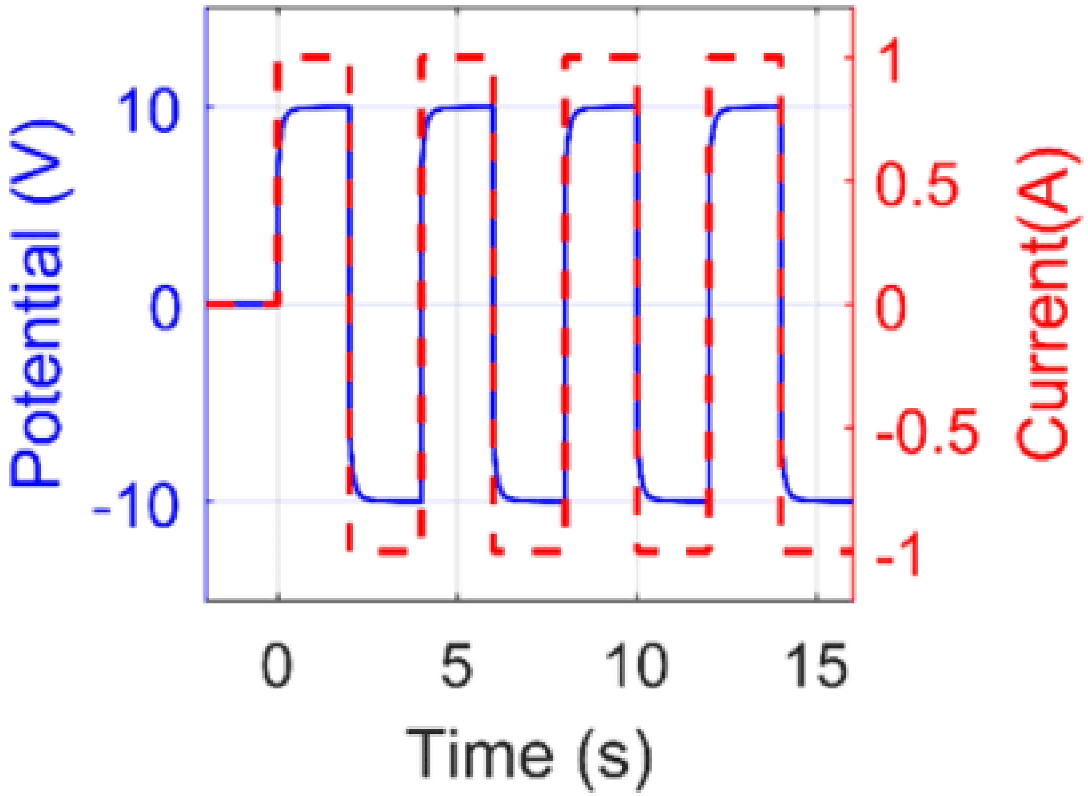
Time Domain EM Measurement

Process data to measure decaying EM field in off (⟷) times

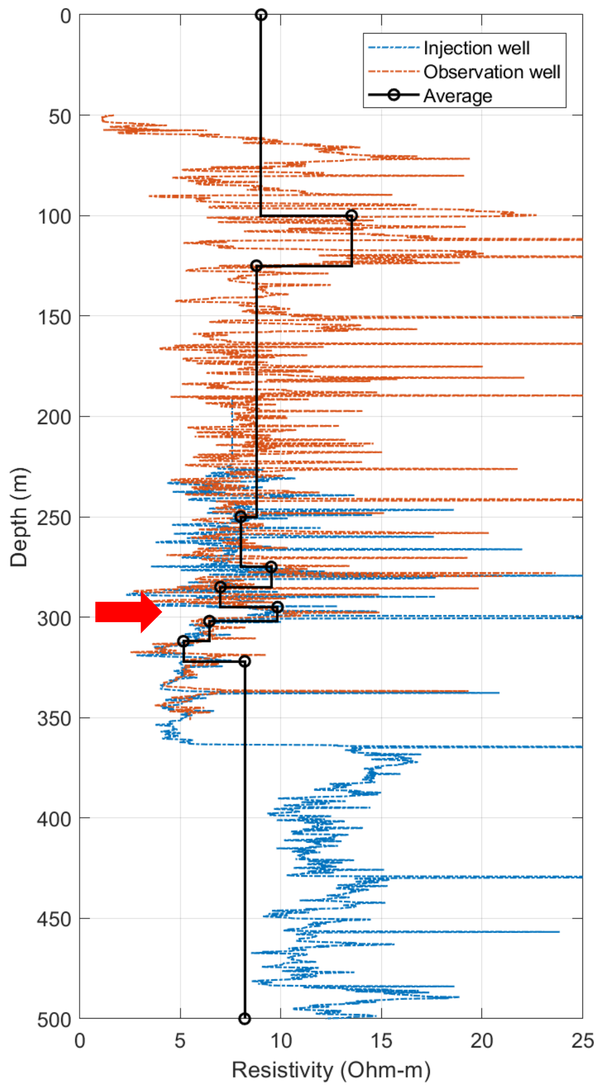


Frequency Domain EM Measurement

Fourier Transform data to measure determine amplitude and phase as a function of frequency



EM Models



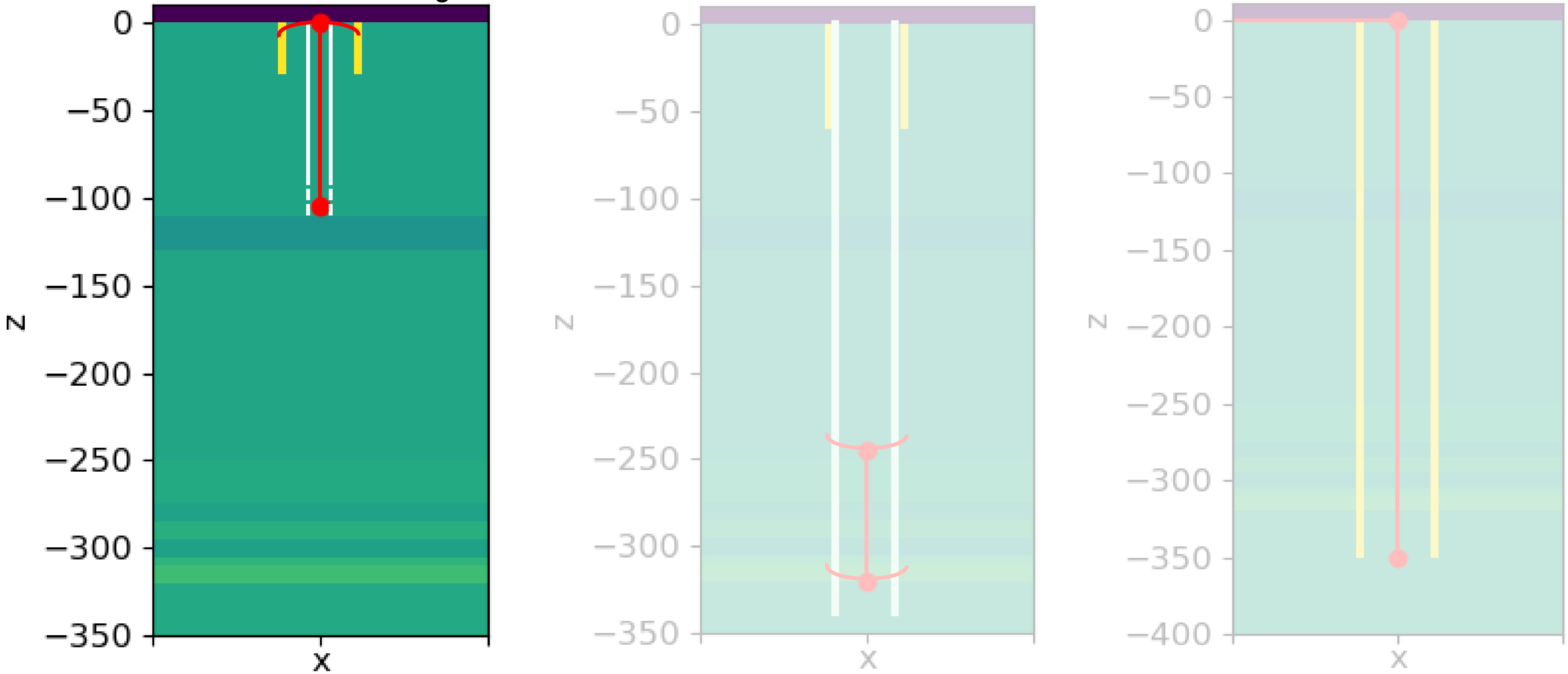
- 1D Layered Electrical Resistivity Model
- CO_2 Plume Resistivity (Archie's law, m=n=2)
  - S_{CO2}=0%: 9.83 Ohm-m
  - S_{CO2}=10%: 12.14 Ohm-m
  - S_{CO2}=20%: 15.36 Ohm-m
  - S_{CO2}=30%: 20.06 Ohm-m
  - S_{CO2}=40%: 27.31 Ohm-m
  - S_{CO2}=50%: 39.32 Ohm-m
  - S_{CO2}=60%: 61.44 Ohm-m
  - S_{CO2}=70%: 109.22 Ohm-m
  - S_{CO2}=80%: 245.75 Ohm-m
- 7m thick, CO_2 plume radius: 100m

Well / Source Construction : Step Off Tx

S1: PVC Cased Water Well with Surface Steel Casing

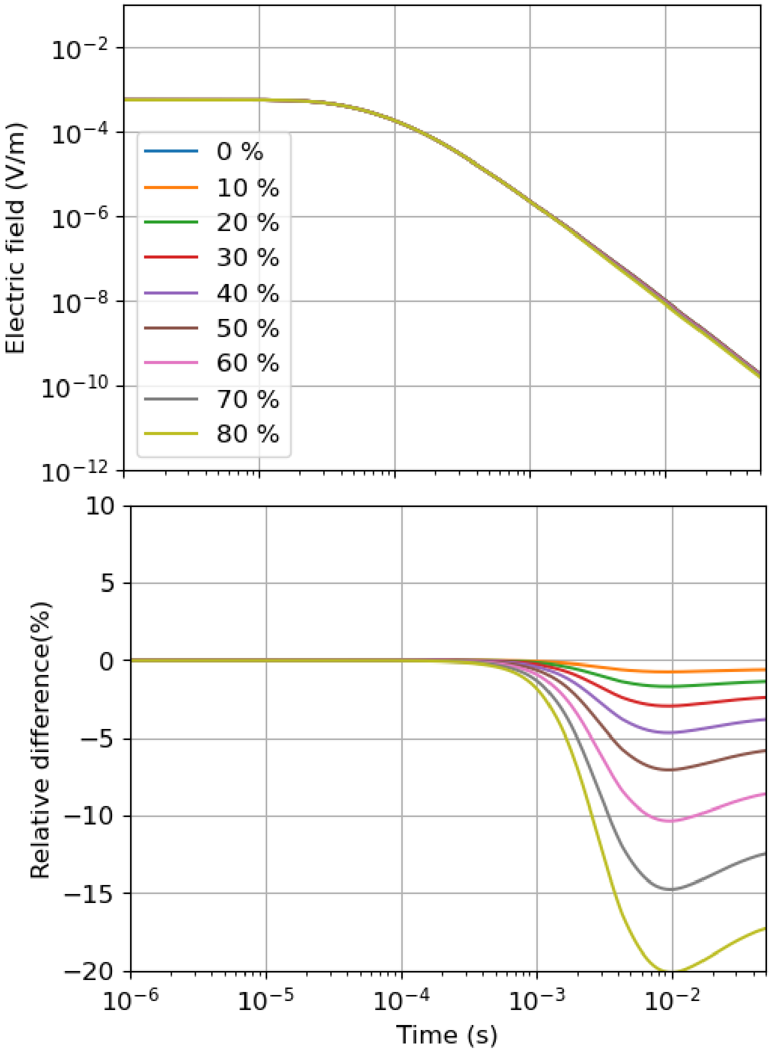
S2: Fiberglass Cased OBS2 with Surface Steel Casing

S3: Steel Cased Well with down-hole and surface electrodes

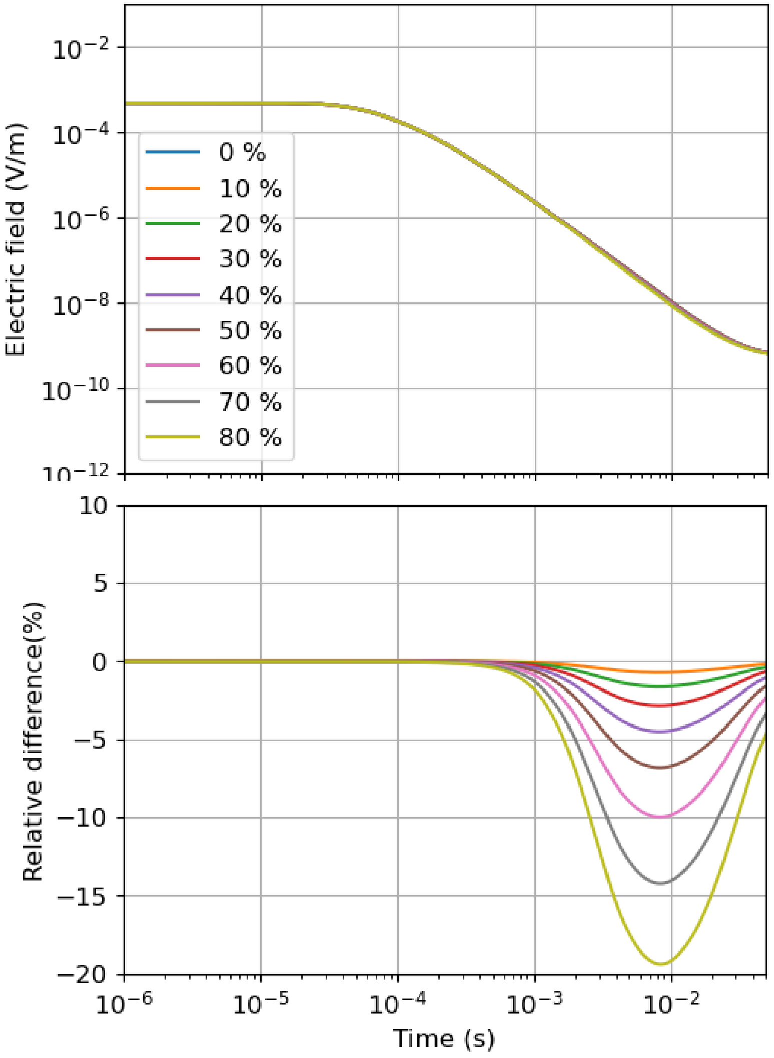


Effect of Surface Casing on Close (50m) Measurements

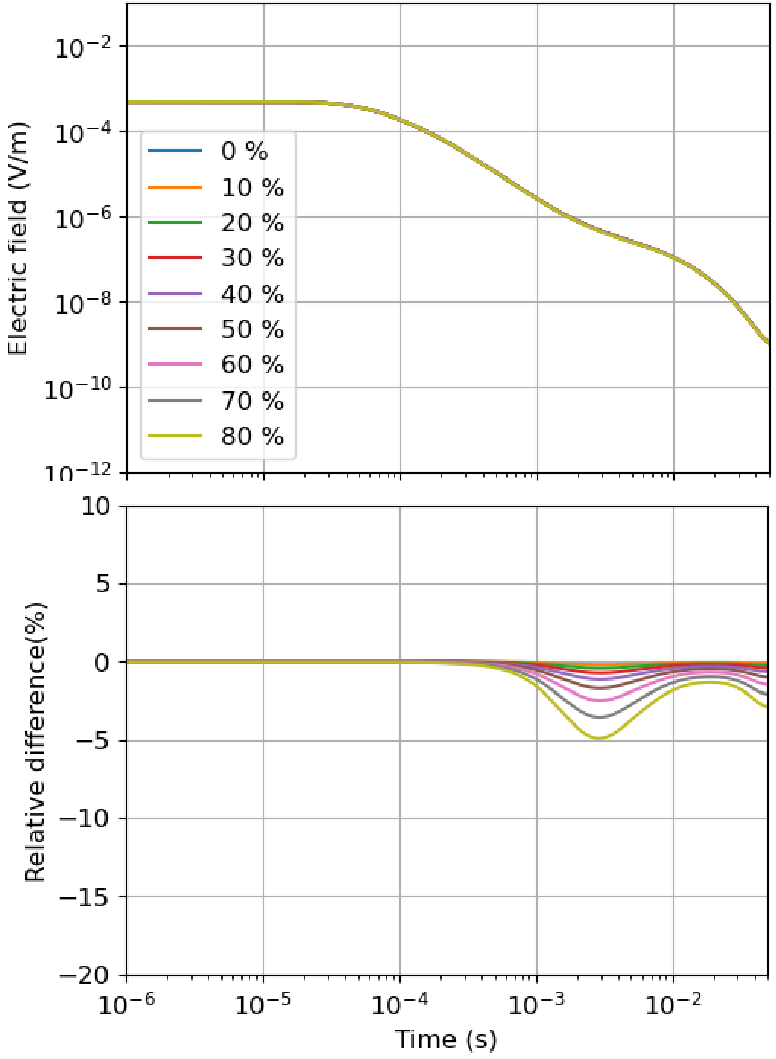
No Steel Casing



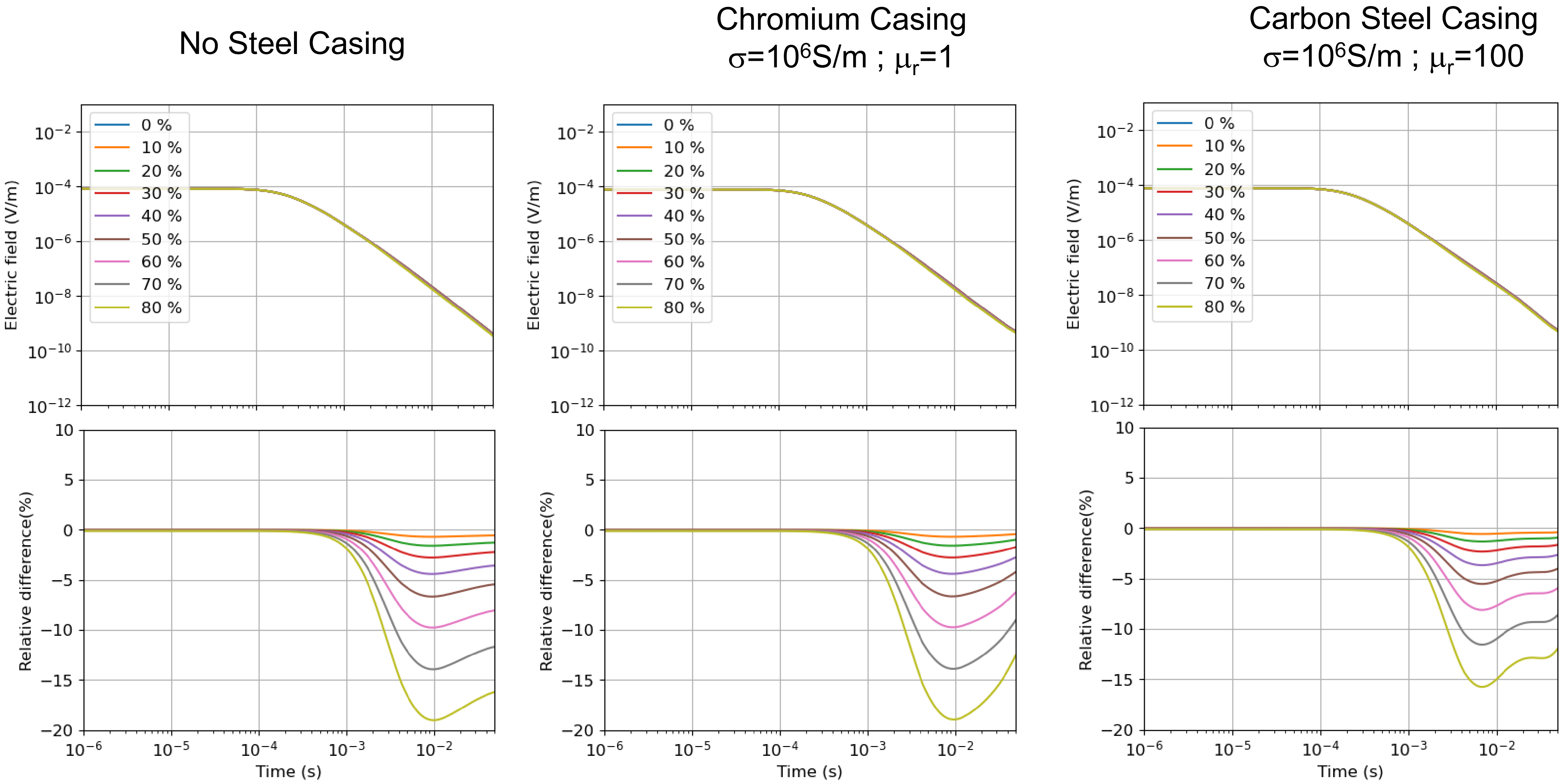
Chromium Casing
$\sigma=10^6$S/m ; $\mu_r=1$



Carbon Steel Casing
$\sigma=10^6$S/m ; $\mu_r=100$

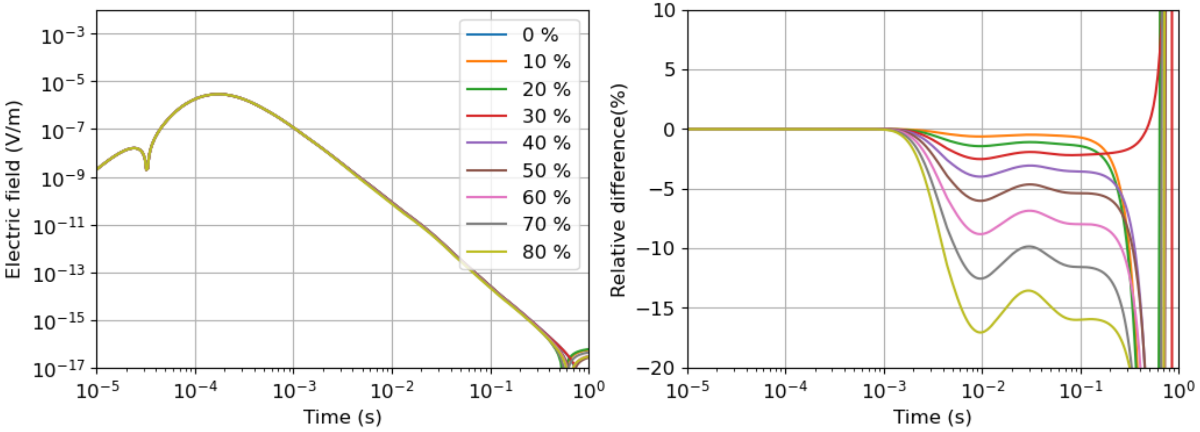


Effect of Moving Receiver to 100m away

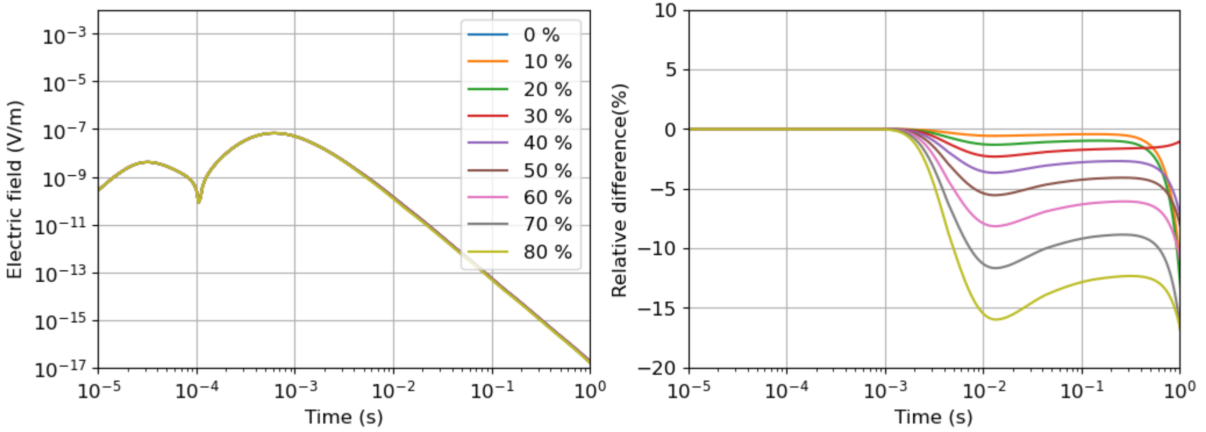


Surface Ex at Further Offsets

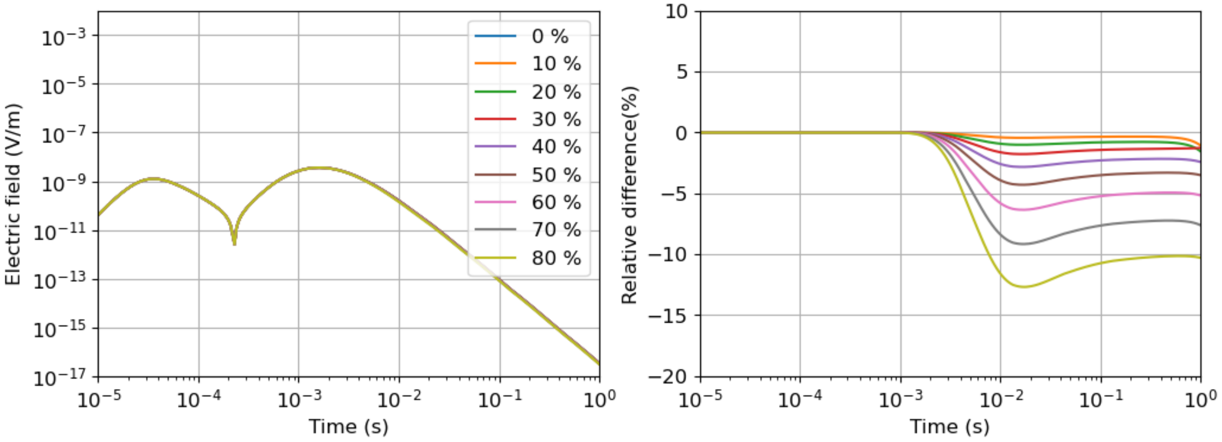
100m offset



200m offset

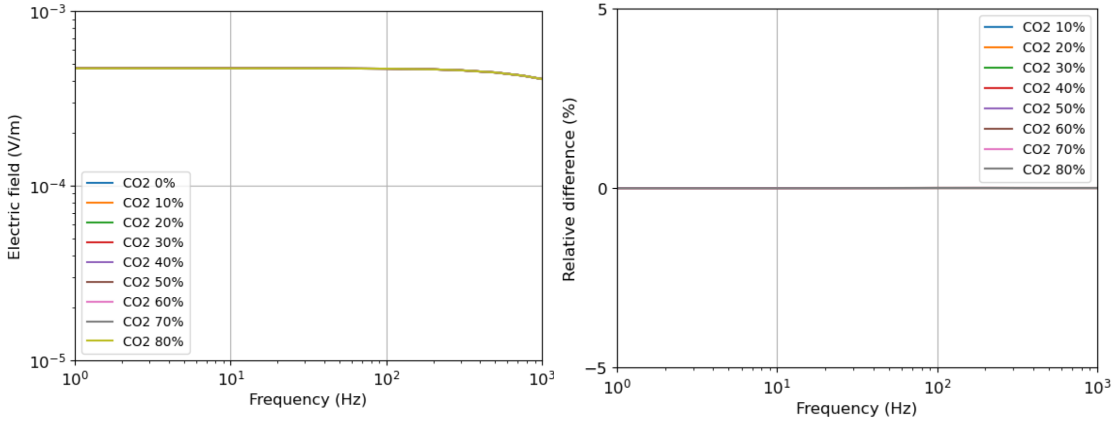


400m offset

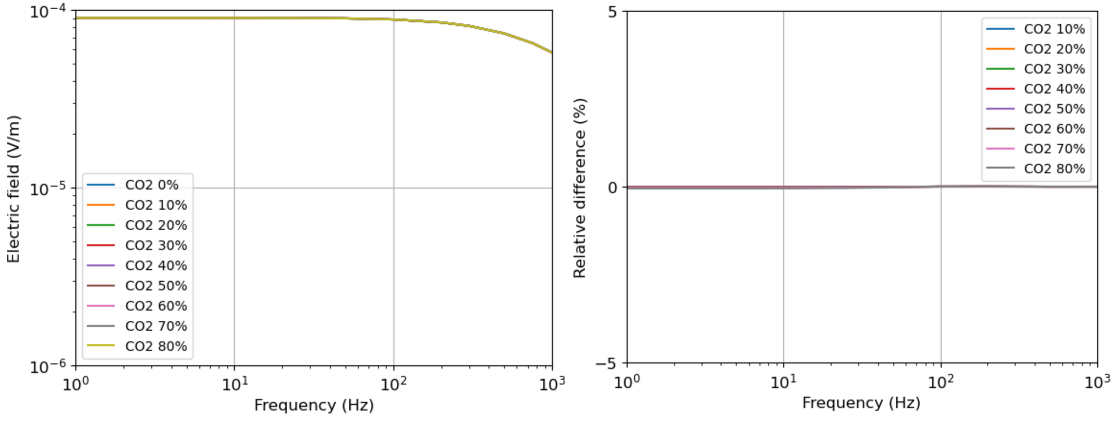


Surface Ex versus Receiver Offset : Freq Domain

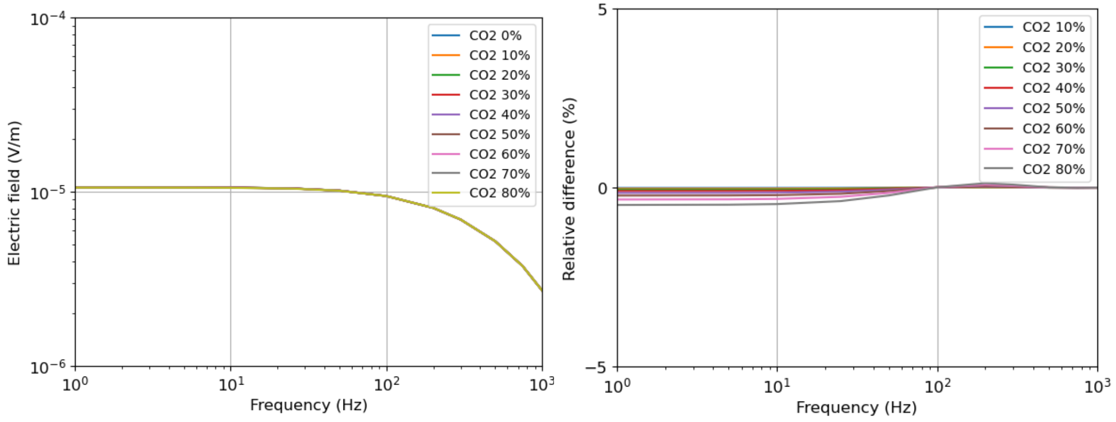
50m offset



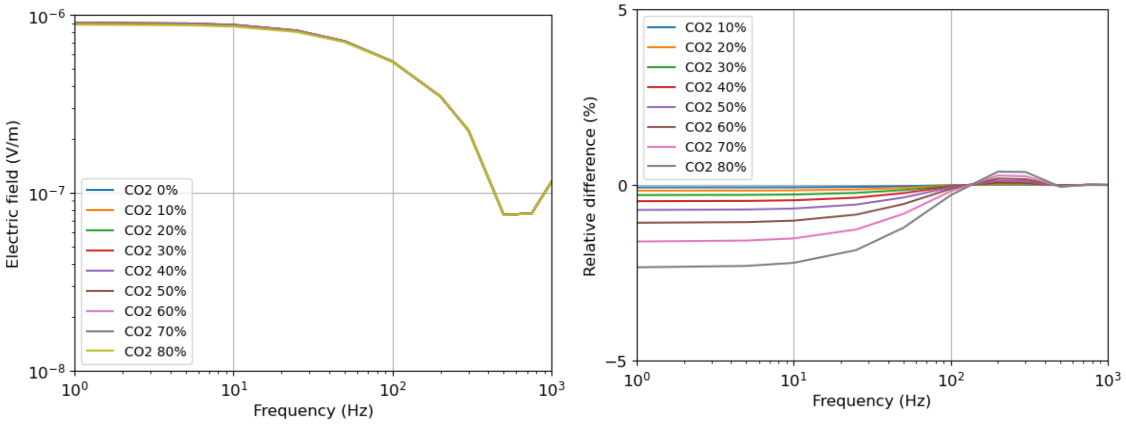
100m Offset



200m offset



400m Offset

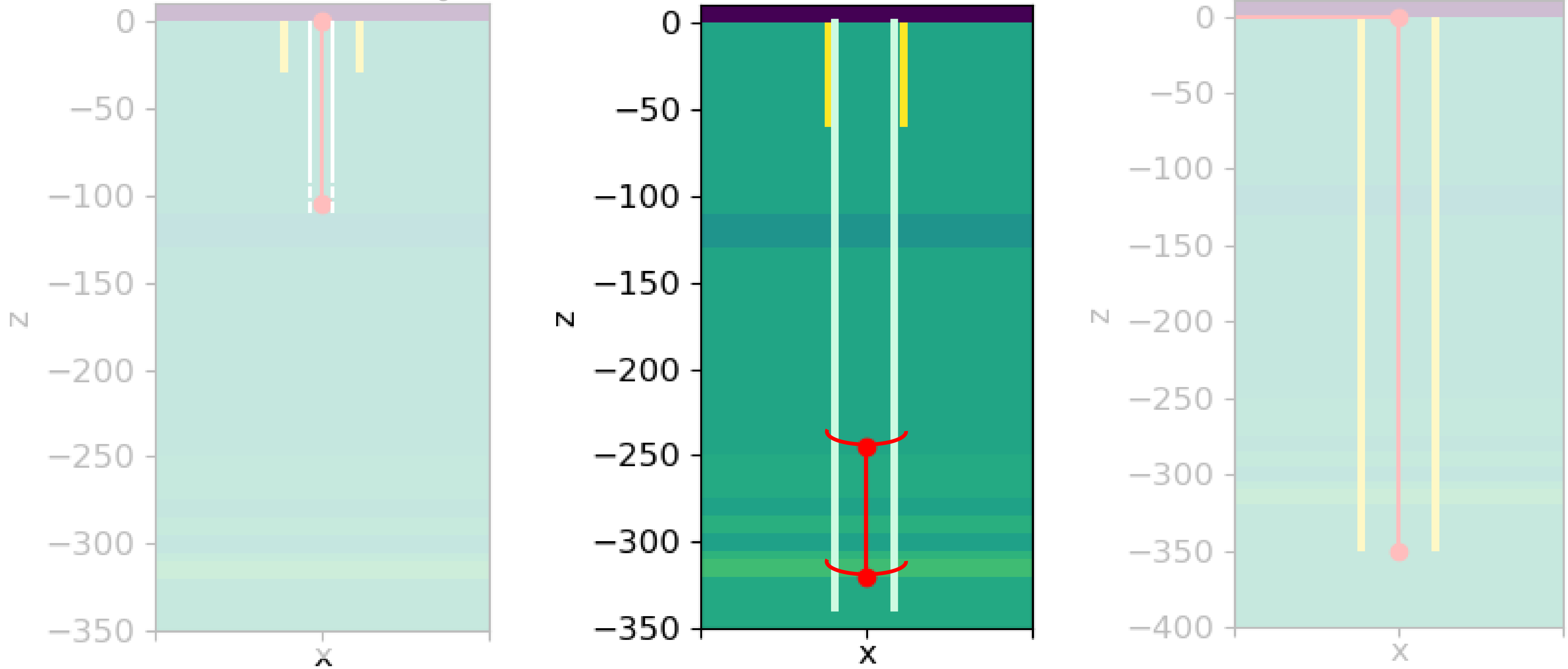


Well / Source Construction

S1: PVC Cased Water Well with Surface Steel Casing

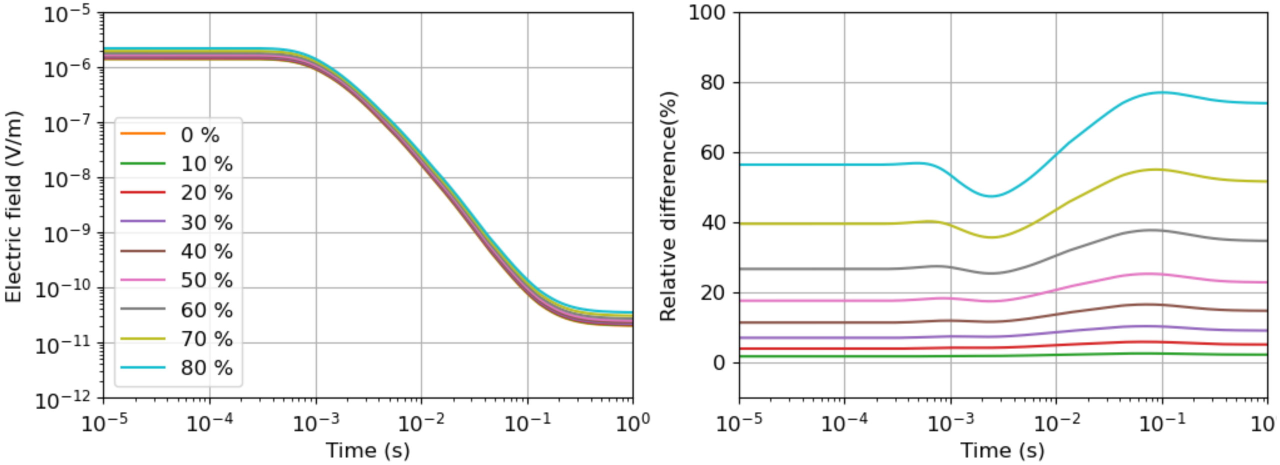
S2: Fiberglass Cased OBS2 with Surface Steel Casing

S3: Steel Cased Well with down-hole and surface electrodes

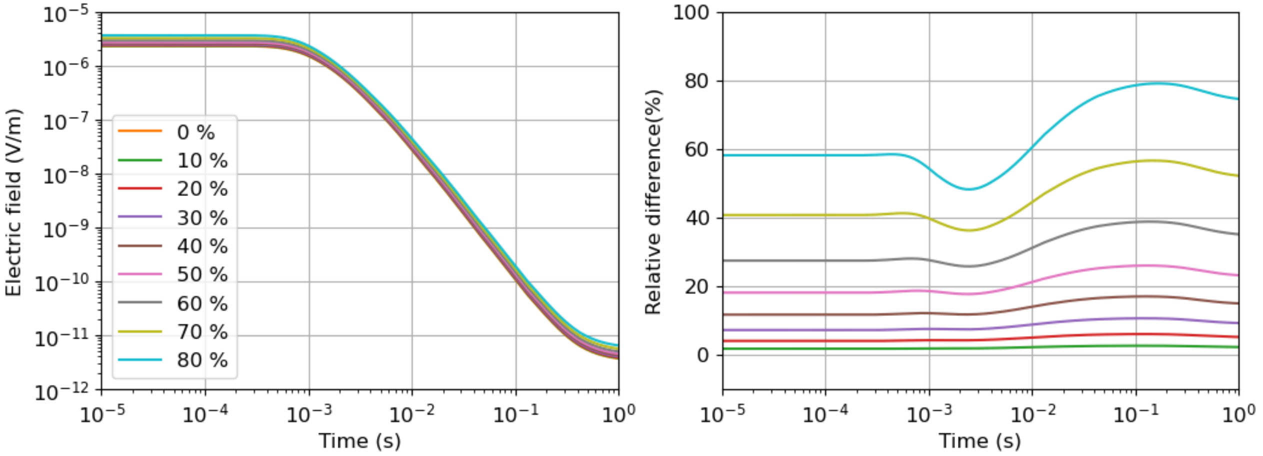


Surface Ex at Different Offsets: Time Domain

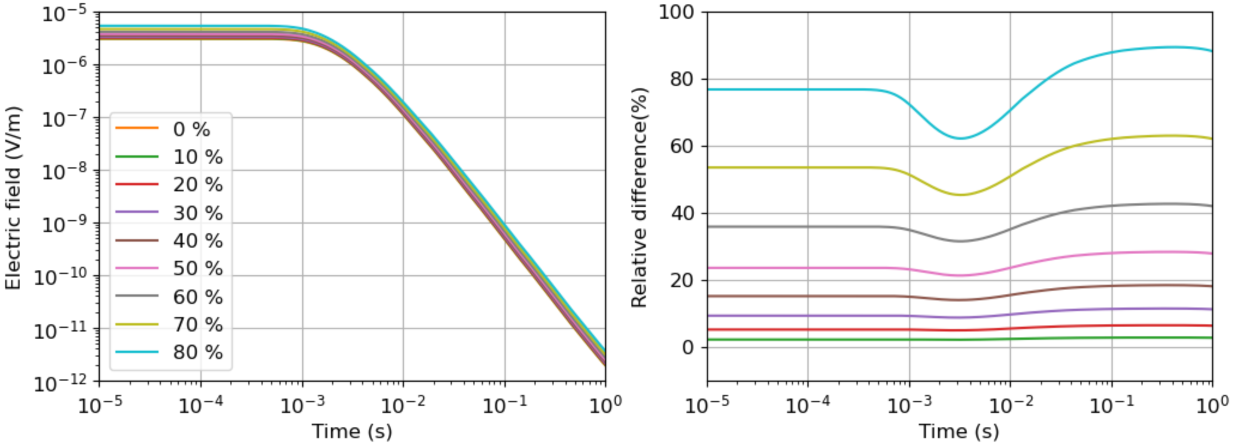
50m offset



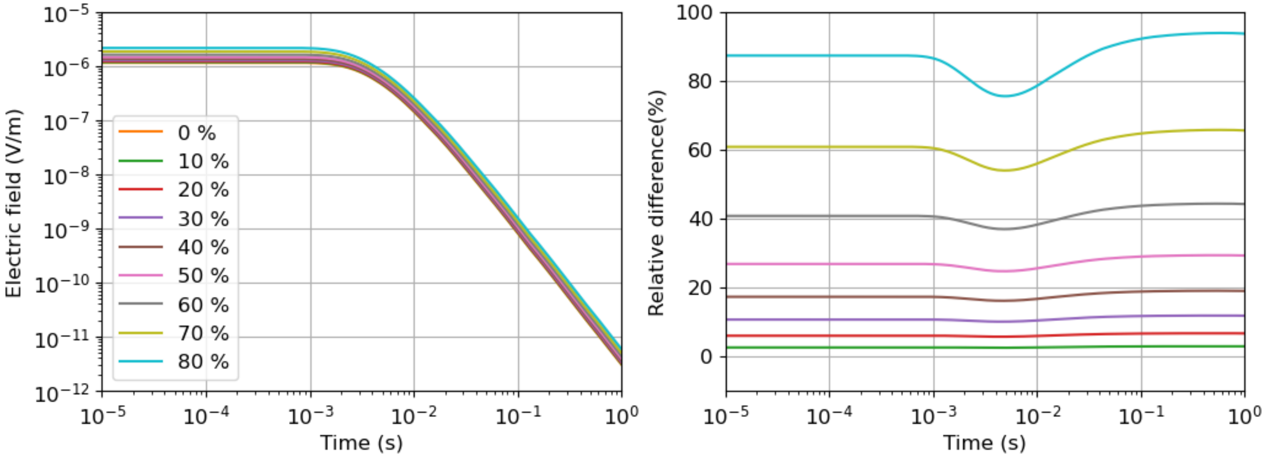
100m Offset



200m offset

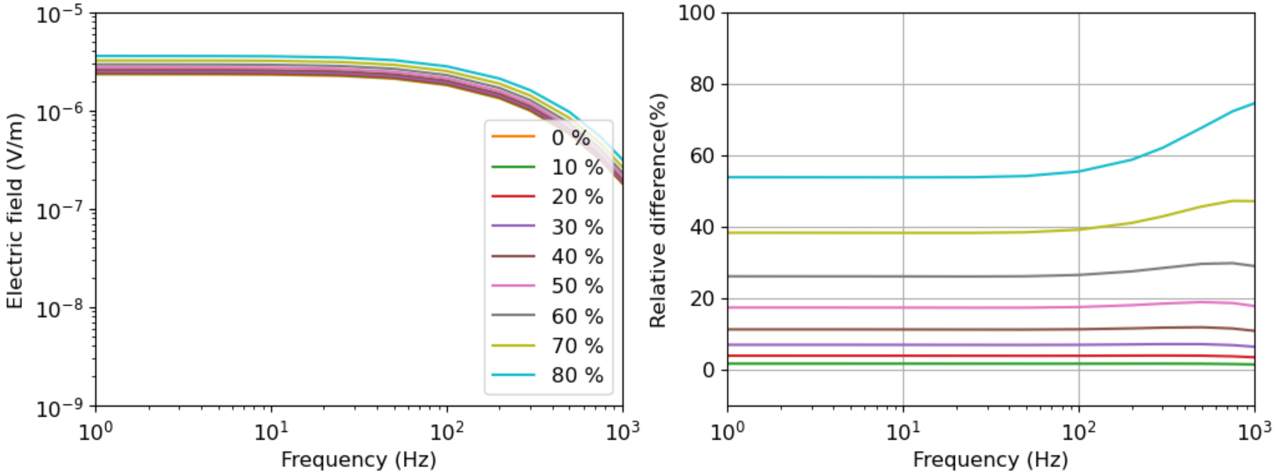


400m offset

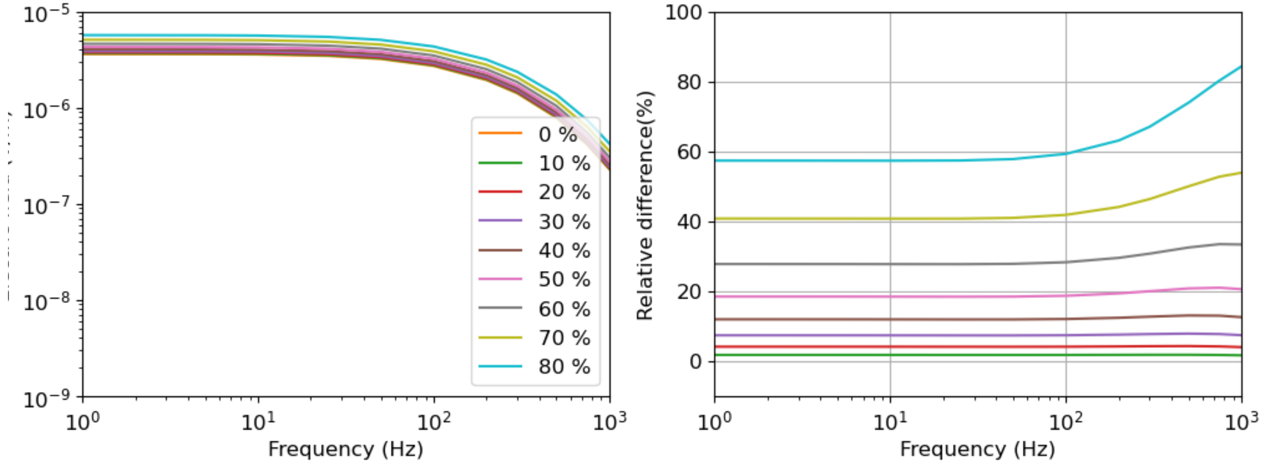


Surface Ex at Different Offsets: Frequency Domain

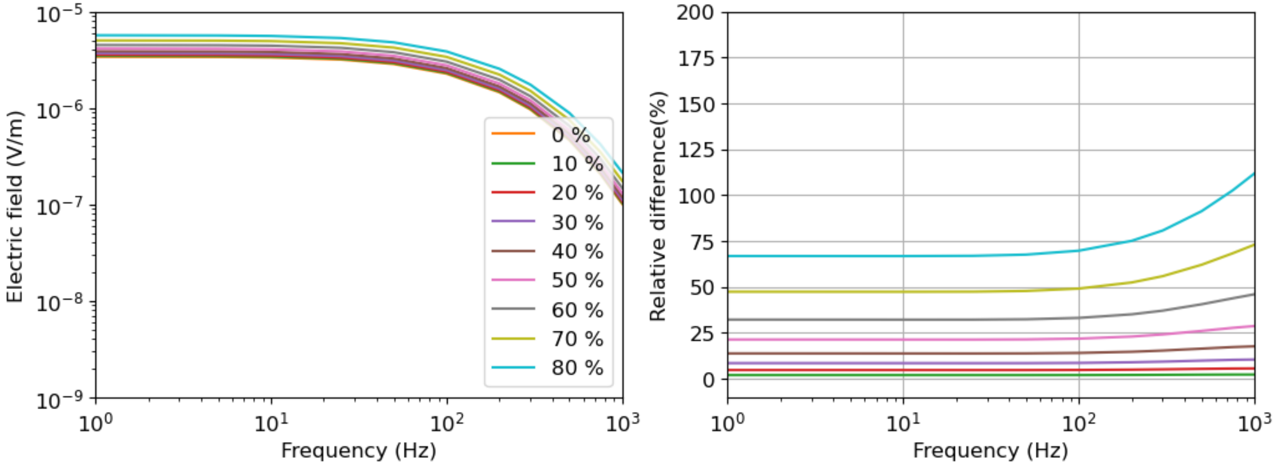
50m offset



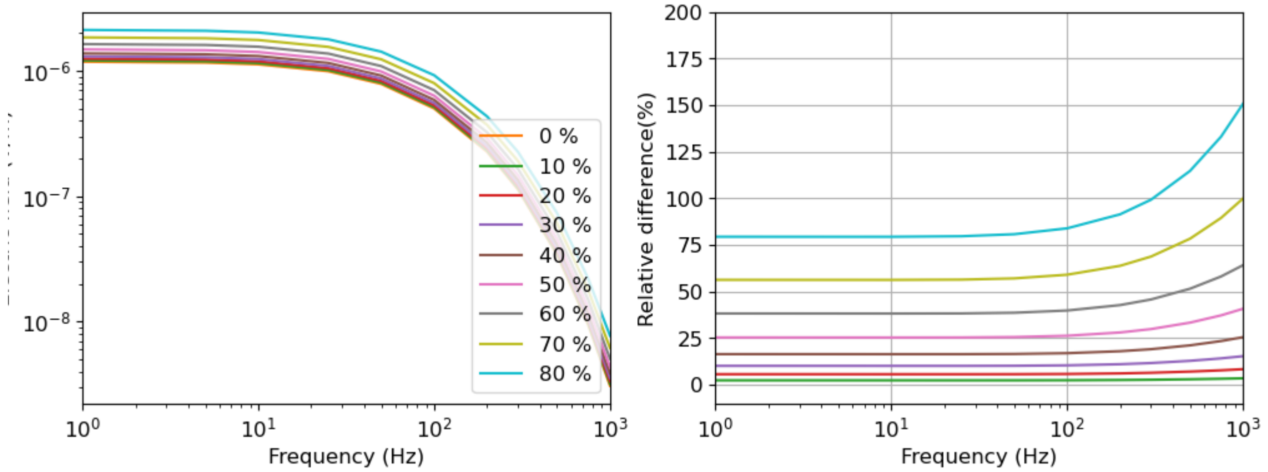
100m Offset



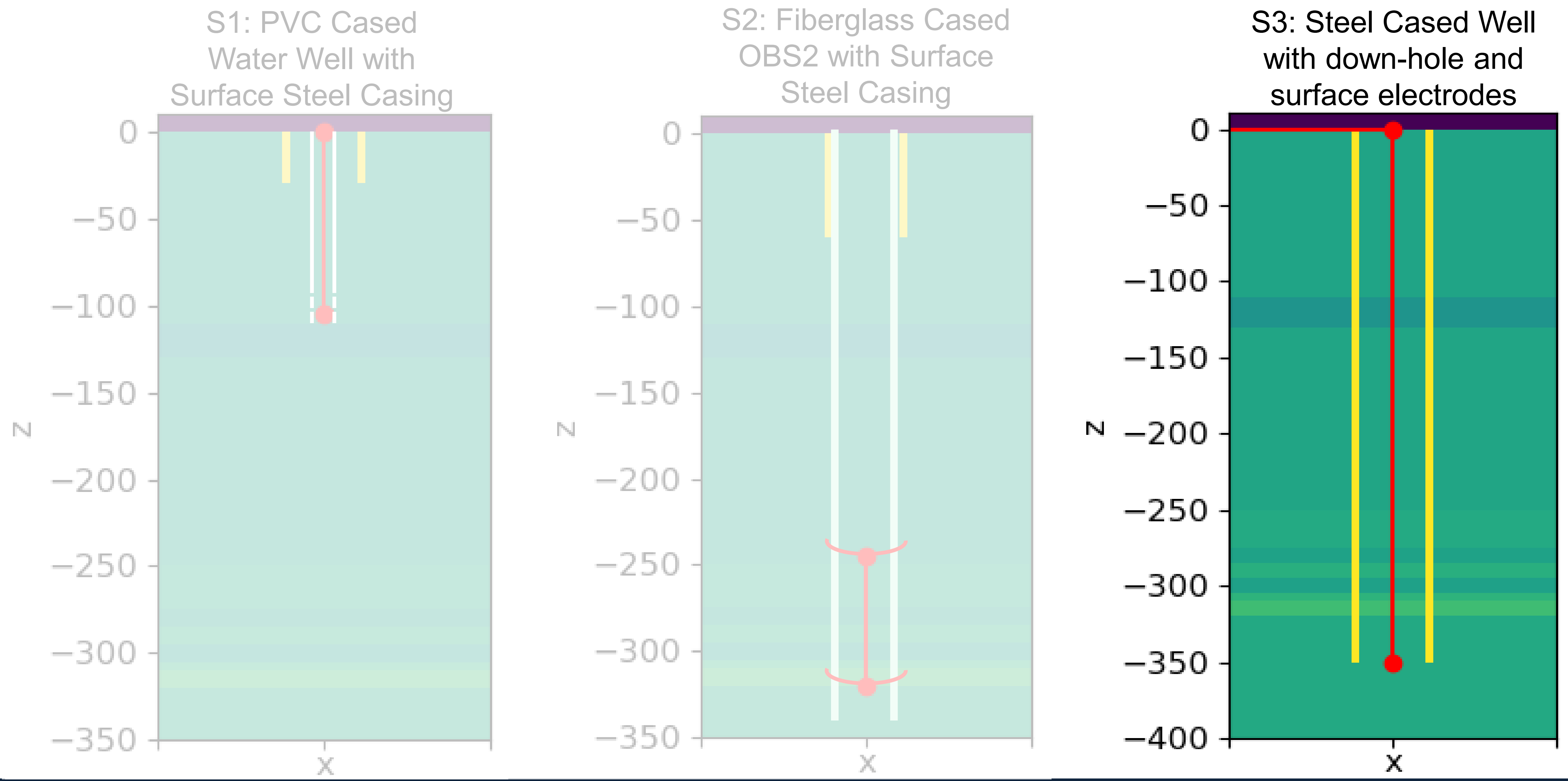
200m offset



400m offset

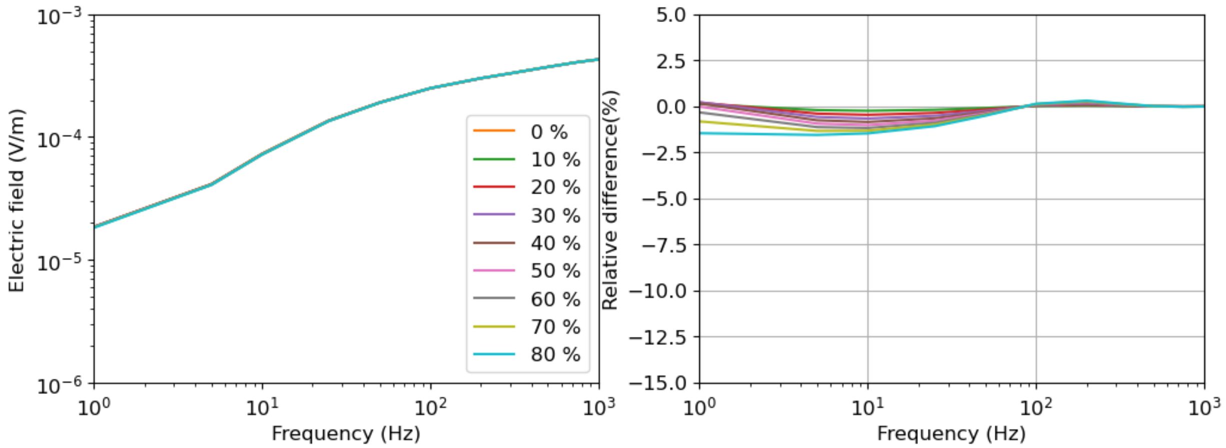


Well / Source Construction : Freq Domain

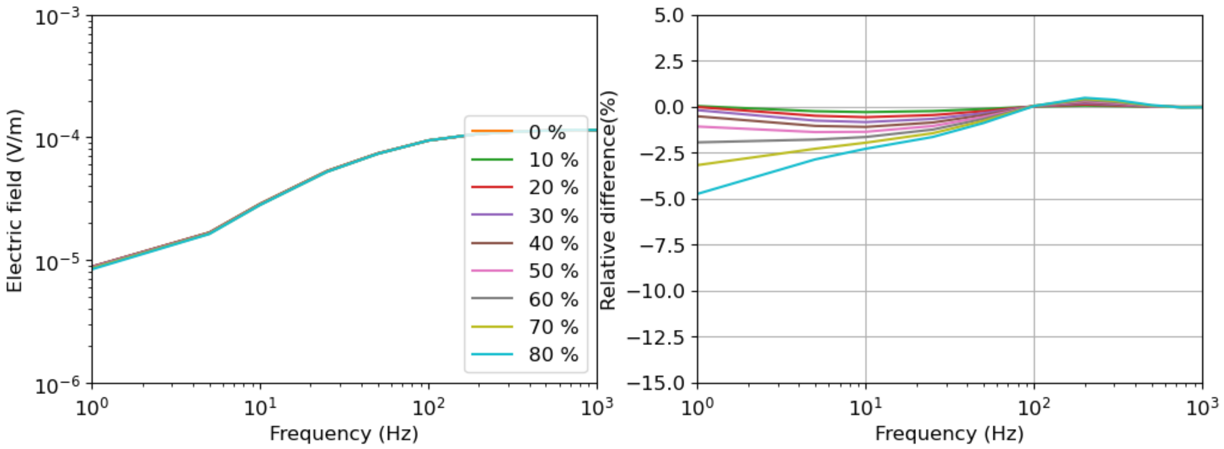


Surface Ex at Different Offsets : Frequency Domain

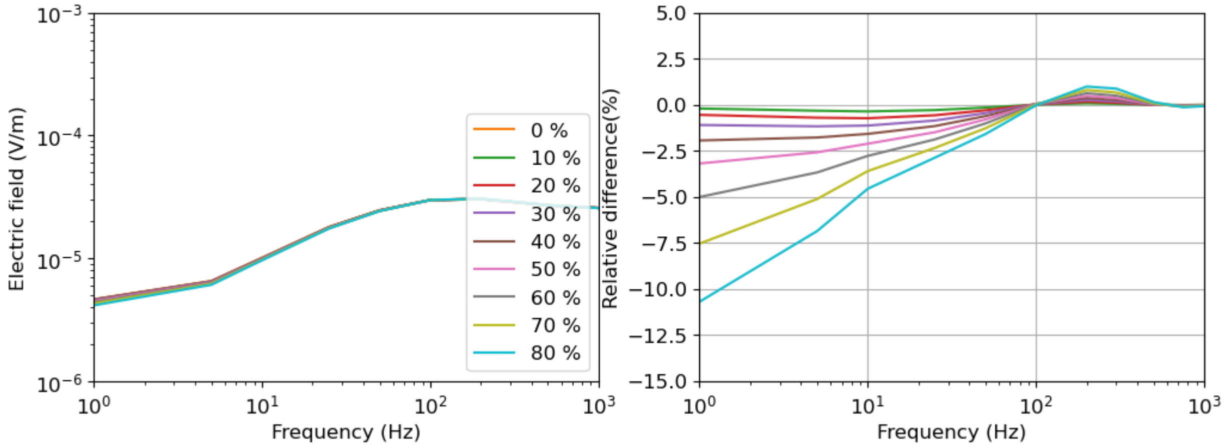
50m offset



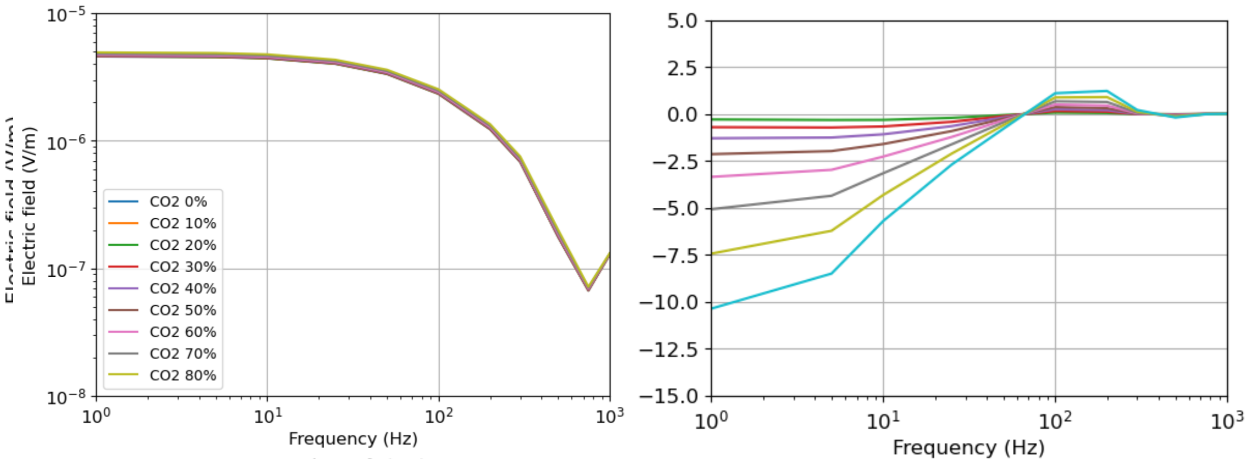
100m Offset



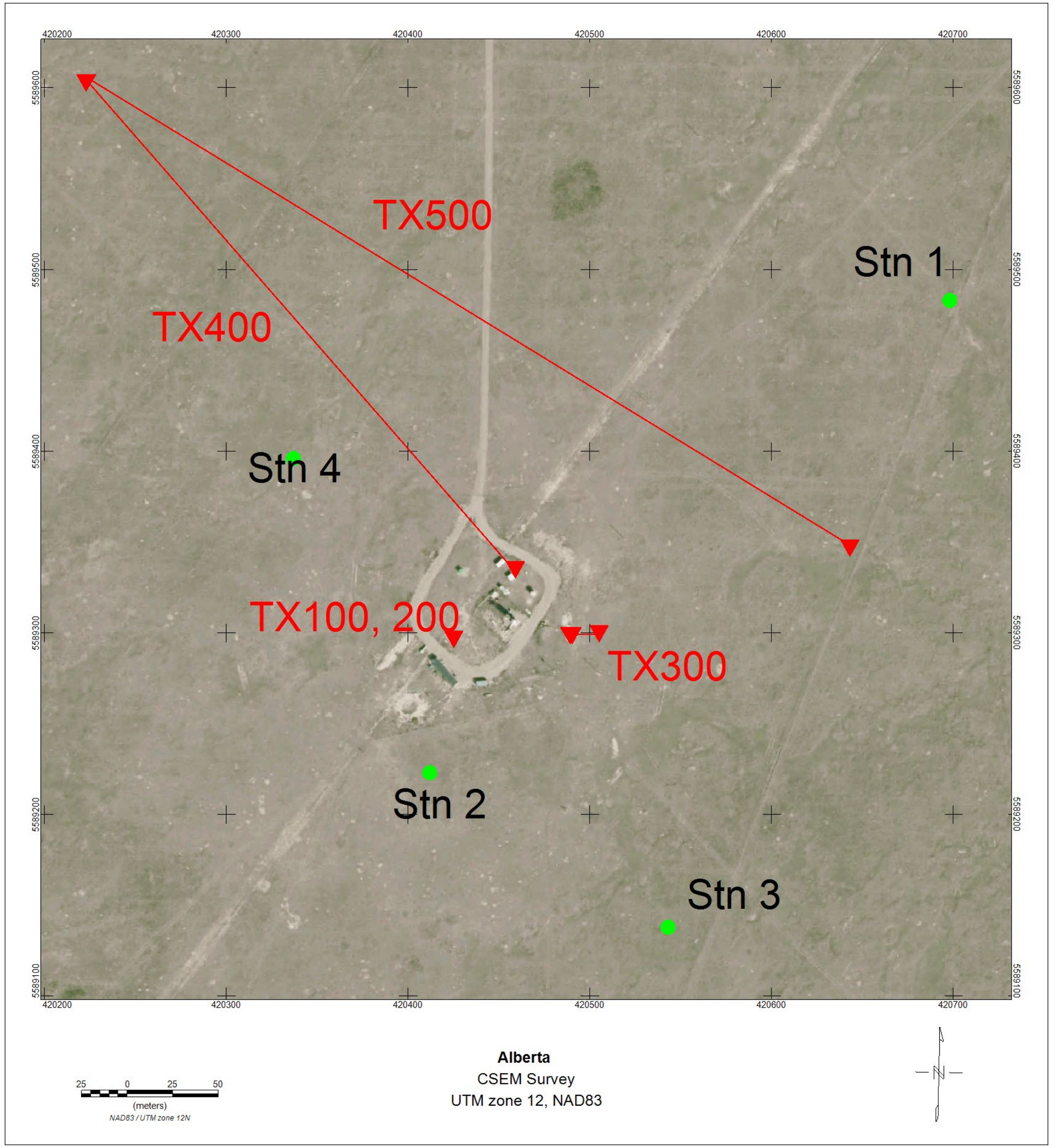
200m offset



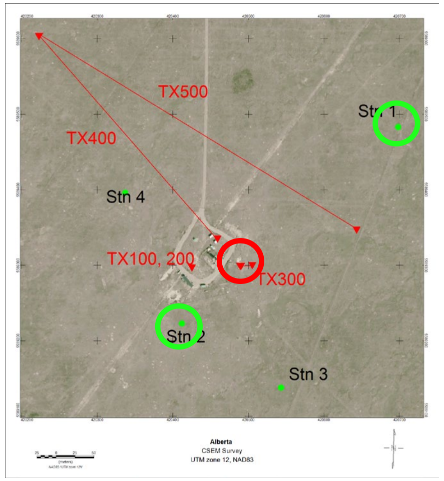
400m offset



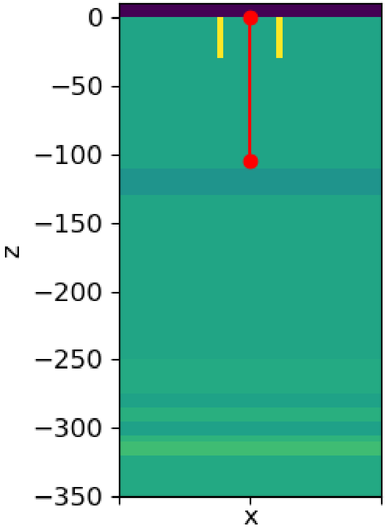
CaMI Field Measurements : July 1-5, 2024



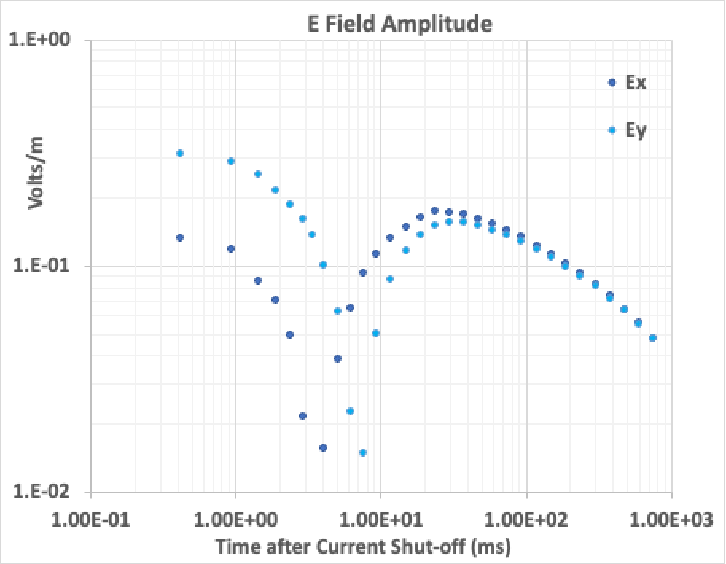
Source 1 or Tx300 – Time Domain

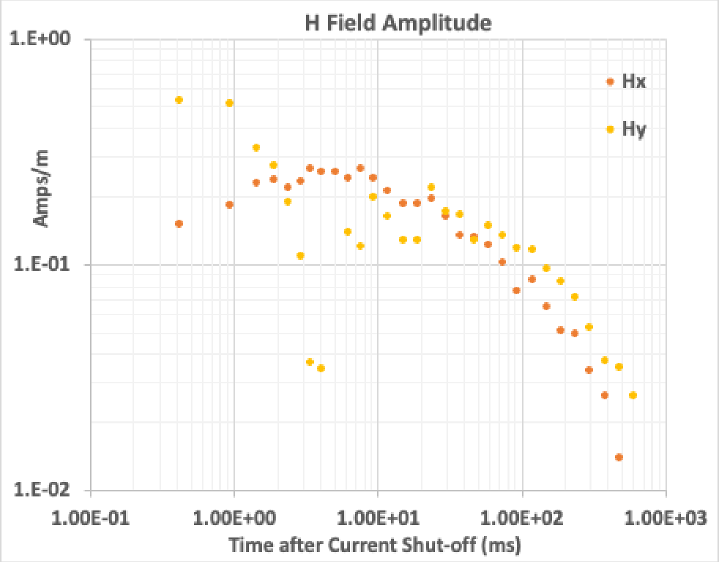


S1 (Tx300) : PVC Cased Water Well with Surface Steel Casing

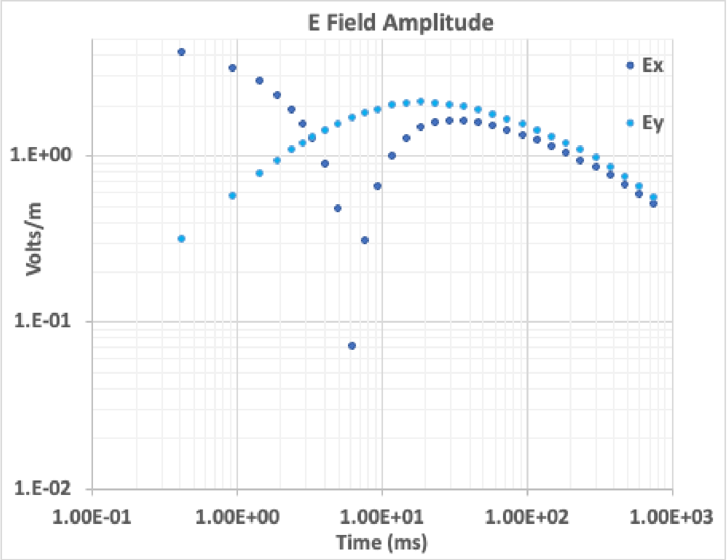


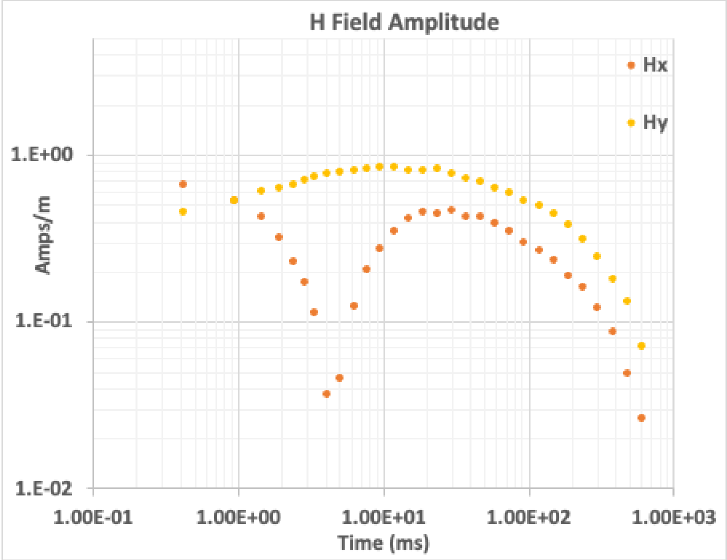
Receiver Site 1



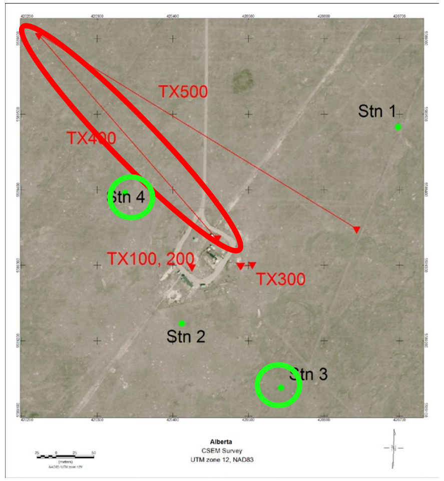


Receiver Site 2

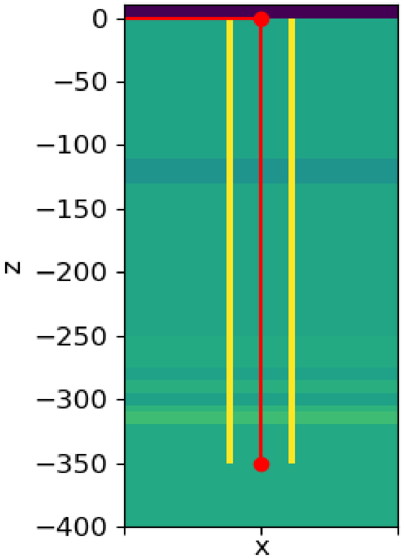




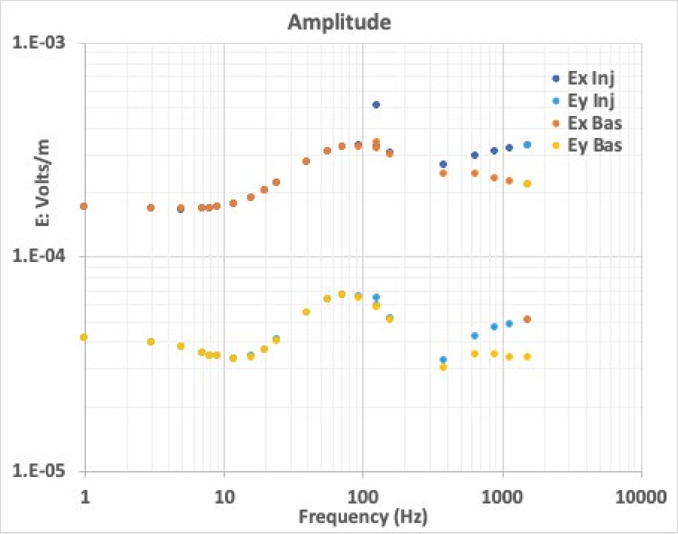
Source 3 or Tx400 – Frequency Domain

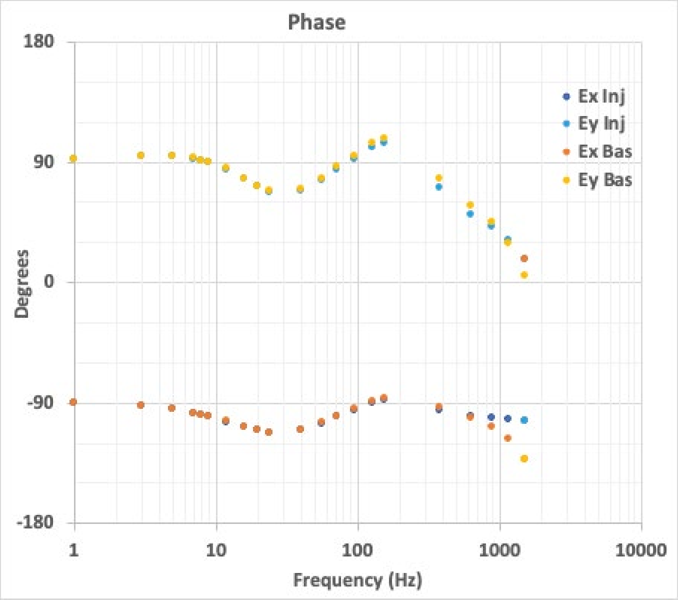


S3 (Tx400) : Steel cased Well energized from the bottom

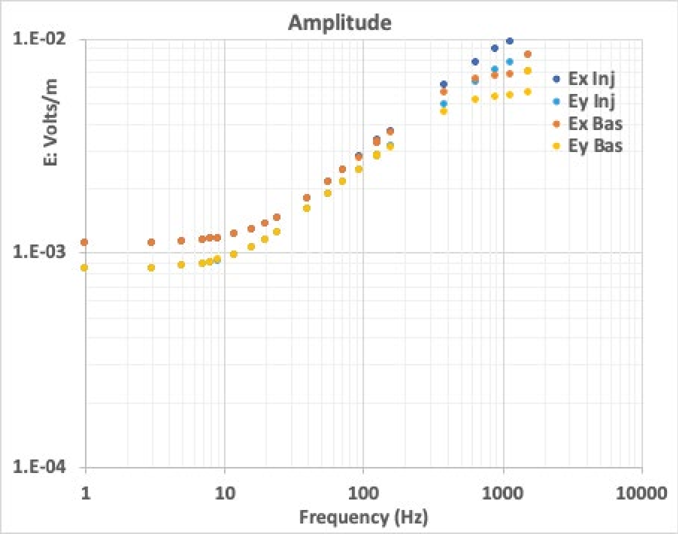


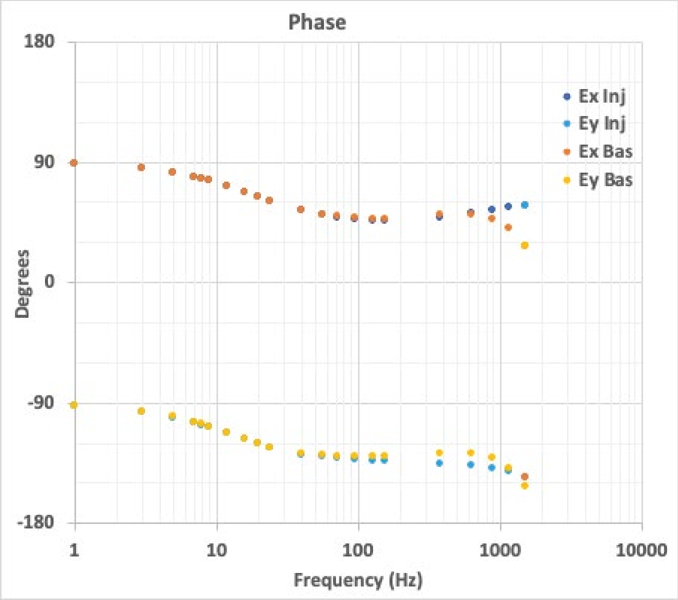
Receiver Site 3



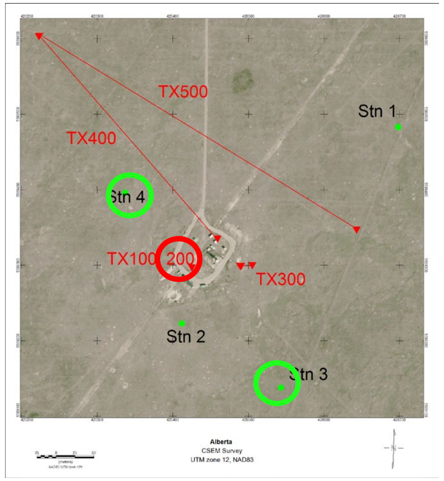


Receiver Site 4

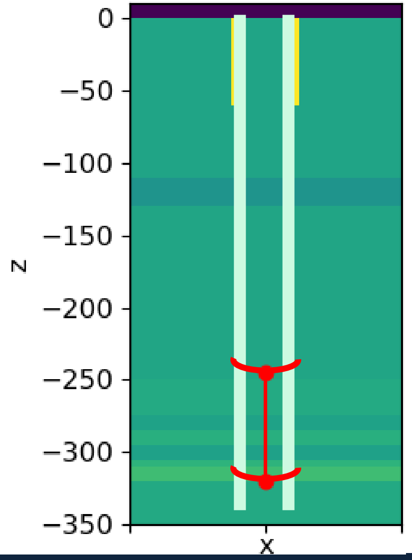




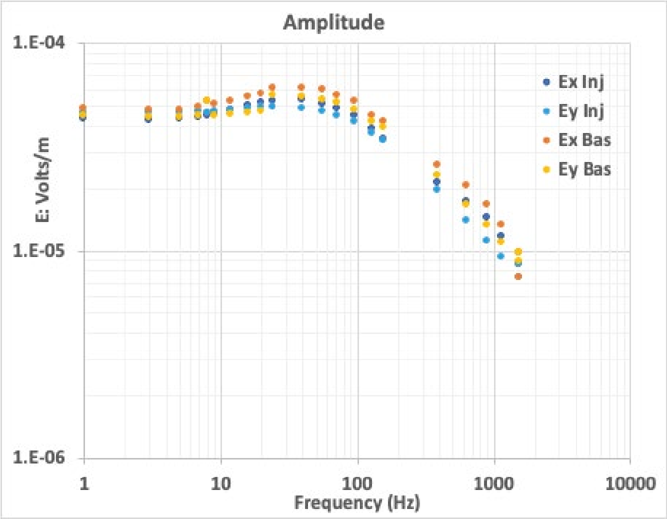
Source 2 or Tx100 – Frequency Domain

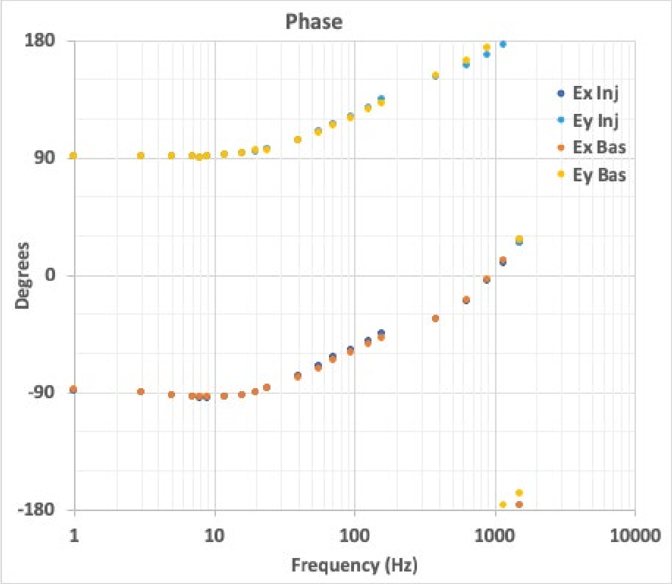


S2 (Tx100) : Fiberglass Well with Deep ERT Electrodes

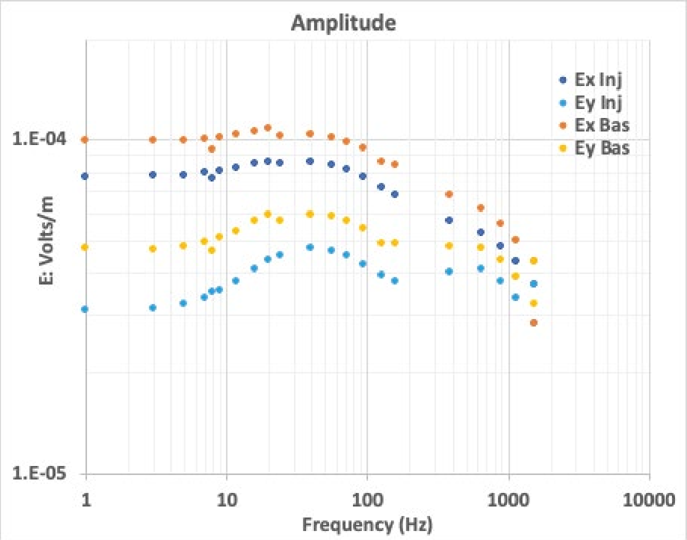


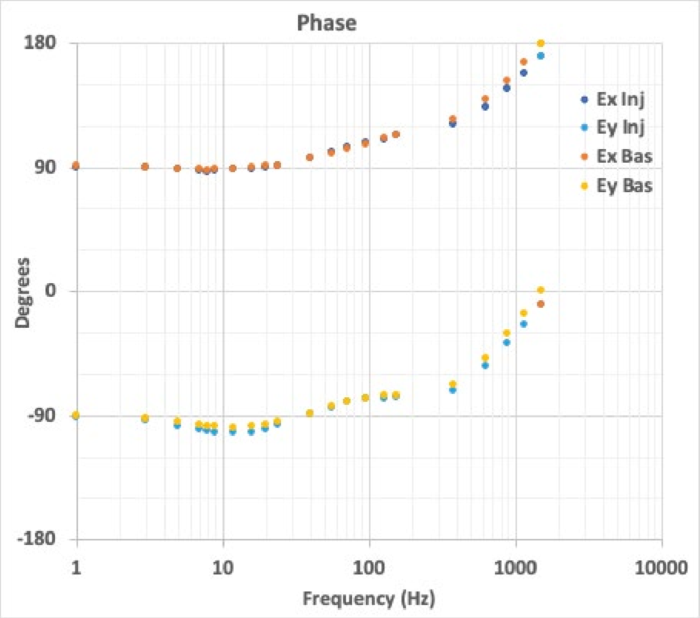
Receiver Site 3





Receiver Site 4





Summary

- Numerical Modeling Shows:
  - Surface vs Deep Dipole - Deep dipole offers better sensitivity
  - Time vs Frequency Domain Measurements
    - For Surface VED Source, time domain measurement more sensitive than frequency domain, especially at close source-receiver offsets
    - For deeper sources, low frequency (DC) response provides similar sensitivity
  - Surface steel casing on transmitter well has significant effect on time domain responses short offsets out to measurement locations 50m to 100m away from well
  - Electrically energized steel casing offers sensitivity better than the shallow VED source in the frequency domain, but not quite as good as VED time-domain measurement

Summary

- Data Acquisition Shows:
  - Surface vs Deep Dipole - Deep dipole data a bit noisier than shallow data
  - Time Domain Measurements - The time domain measurements for Tx100 and Tx300 show sign flips indicating that either
    - The dipoles aren't vertical or
    - There is significant 3D structure or infrastructure to distort the fields or
    - The steel casing segments are producing an IP effect?
  - The frequency domain results with the CO_2 pump off and then on show interesting results…. This will need additional research and repeat measurements to prove
  - The next round of measurements are scheduled for the week of September 30

Funding Acknowledgement

- Most of the project funding for LBNL’s work is provided by the US DOE via Field Work Proposal number FP00015750.
- Other research members of the ACT4 SPARSE project include SINTEF Norway who serve as the international project lead, The University of Calgary, and Carbon Management Canada.

Additional Acknowledgements

Chevron

- Funded LBNL at $98k to date to pay for equipment rental

Zonge International

- Providing cost effective equipment rental and training

UBC

- Using UBC codes (SIMPEG 2D and 3D) for modeling