Functionality and application opportunities for the NRAP Passive Seismic Monitoring Tool

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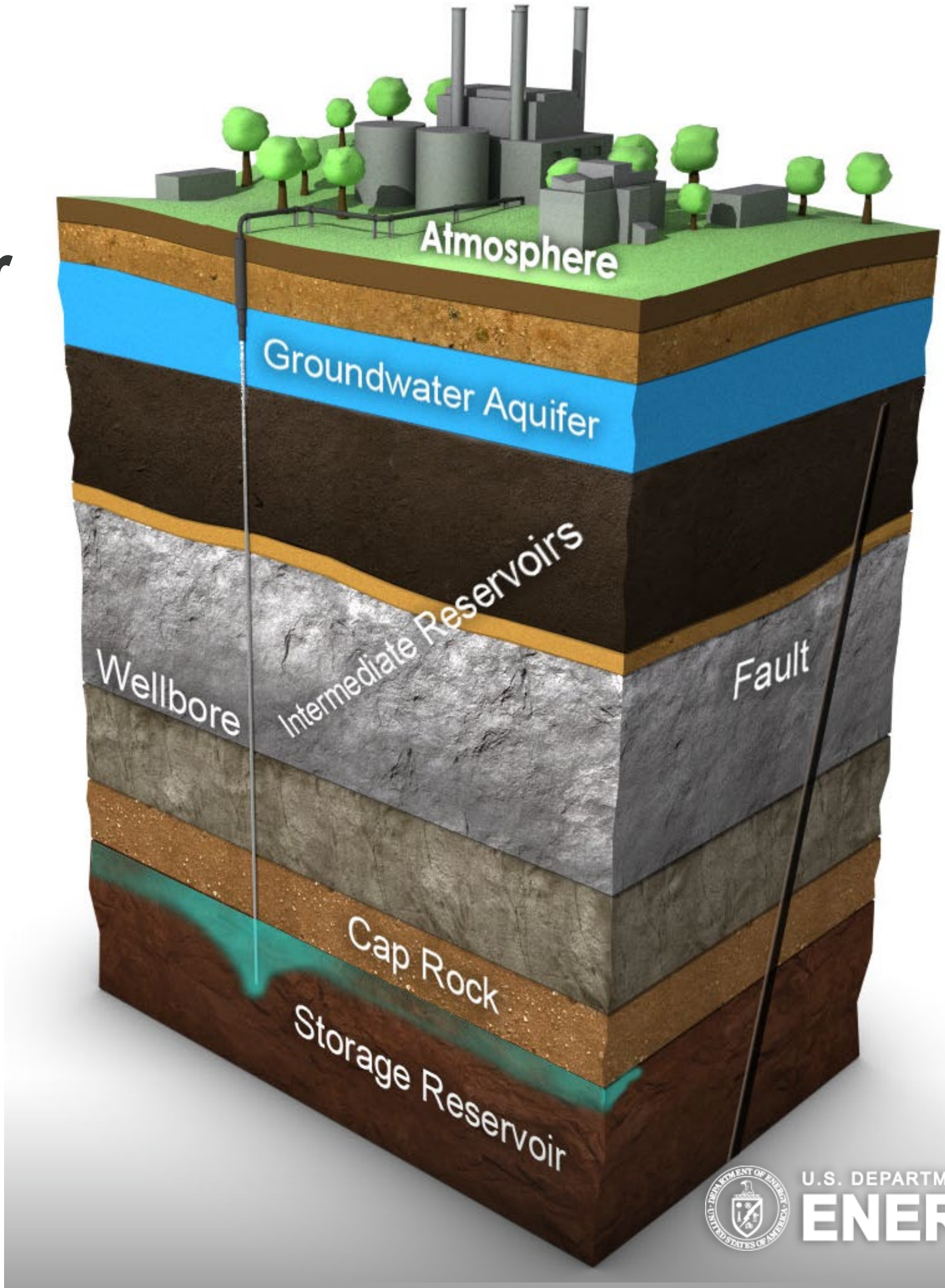
(LA-UR-23-26509)

National Risk Assessment Partnership



U.S. DEPARTMENT OF ENERGY

NRAP tool for microseismic monitoring design

- An NRAP tool for optimal design of microseismic monitoring network is available at NETL EDX for geologic carbon storage and other microseismic monitoring applications: https://edx.netl.doe.gov/user/register

Comments and Questions:

NRAP@NETL.doe.gov

NRAP Website: https://edx.netl.doe.gov/nrap/

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Objectives

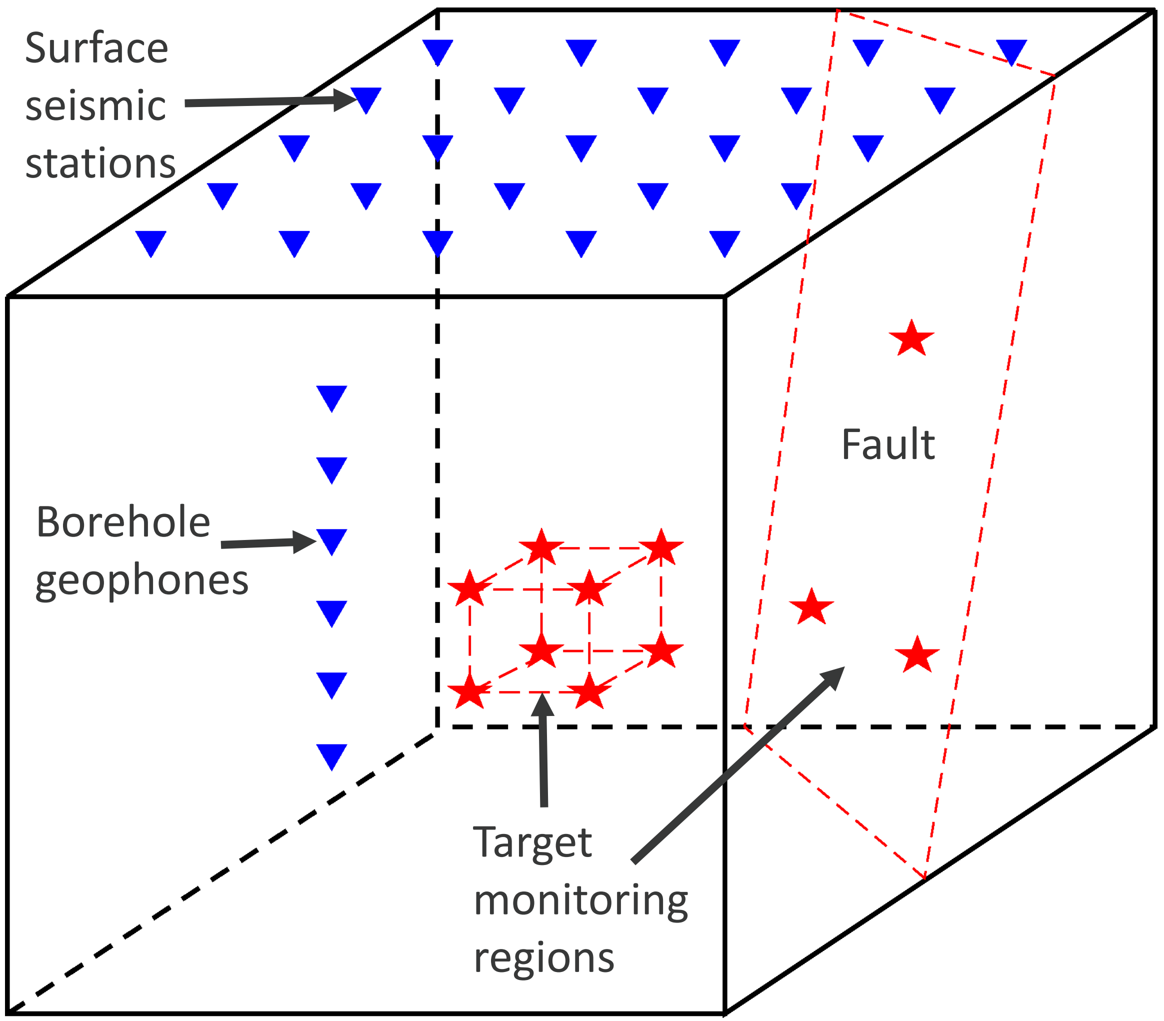
- Develop a tool for optimal design of microseismic monitoring network using surface and/or borehole geophones for cost-effective microseismic monitoring at geologic carbon storage sites and for other microseismic monitoring applications.
- Demonstrate an example application of the tool to the Farnsworth CO_2-EOR field, Texas, the field demonstration site of the Phase III of the Southwest Regional Partnership on Carbon Sequestration.

Contents

- The NRAP tool: Optimal Design of Microseismic Monitoring Network
- Example application to the Farnsworth CO_2-EOR field, Texas

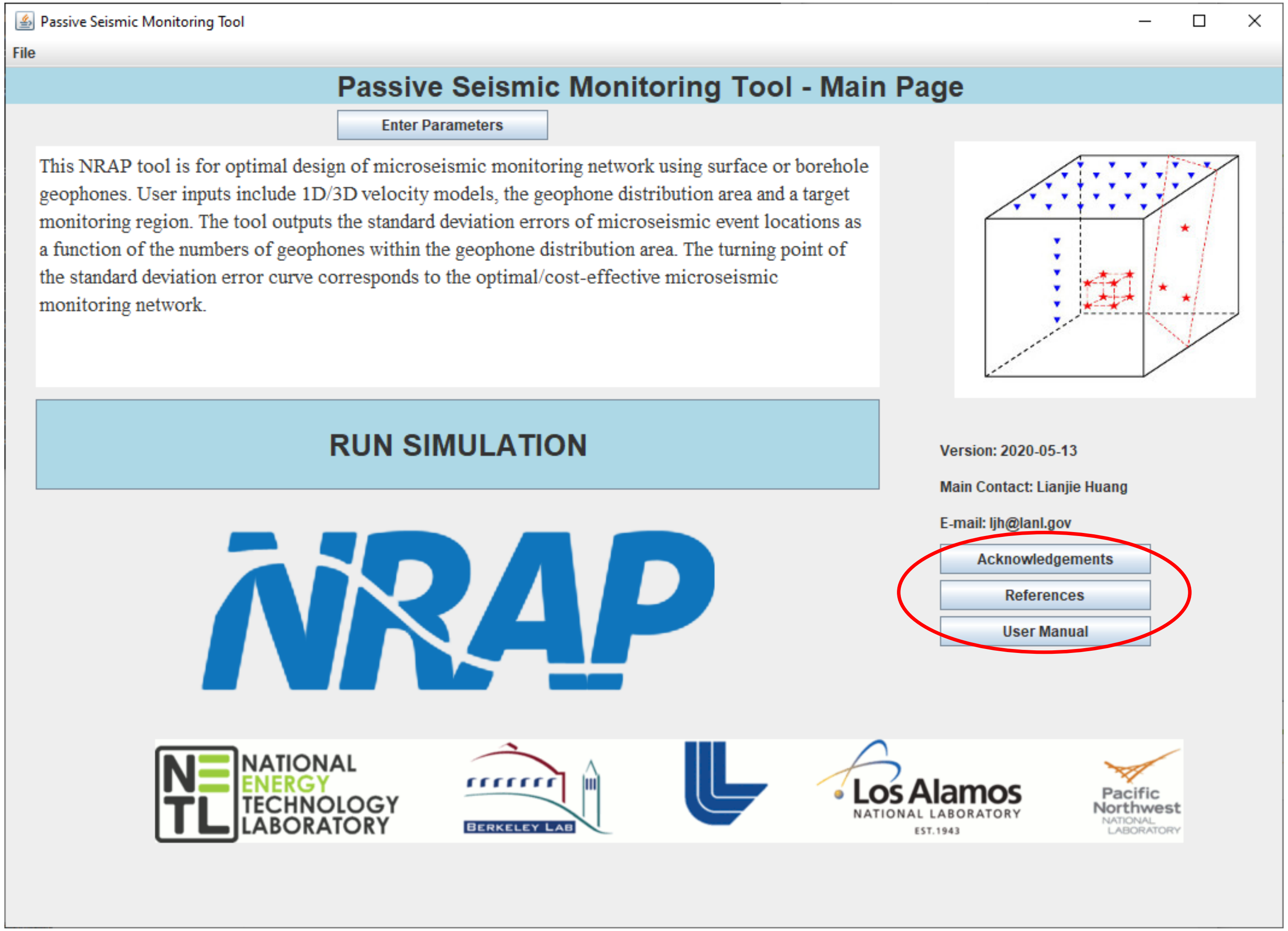
Microseismic Monitoring Network Design

- Design an optimal monitoring network to reliably locate induced microseismic events cost effectively.
- Based on the relationship between the hypocenter uncertainty of microseismic events (red stars) within the target monitoring regions (red dashed box) and the geophone distribution (blue triangles).
- Applicable to any geologic carbon storage sites and other microseismic monitoring applications.
- Can use surface seismic stations and/or borehole geophone arrays.

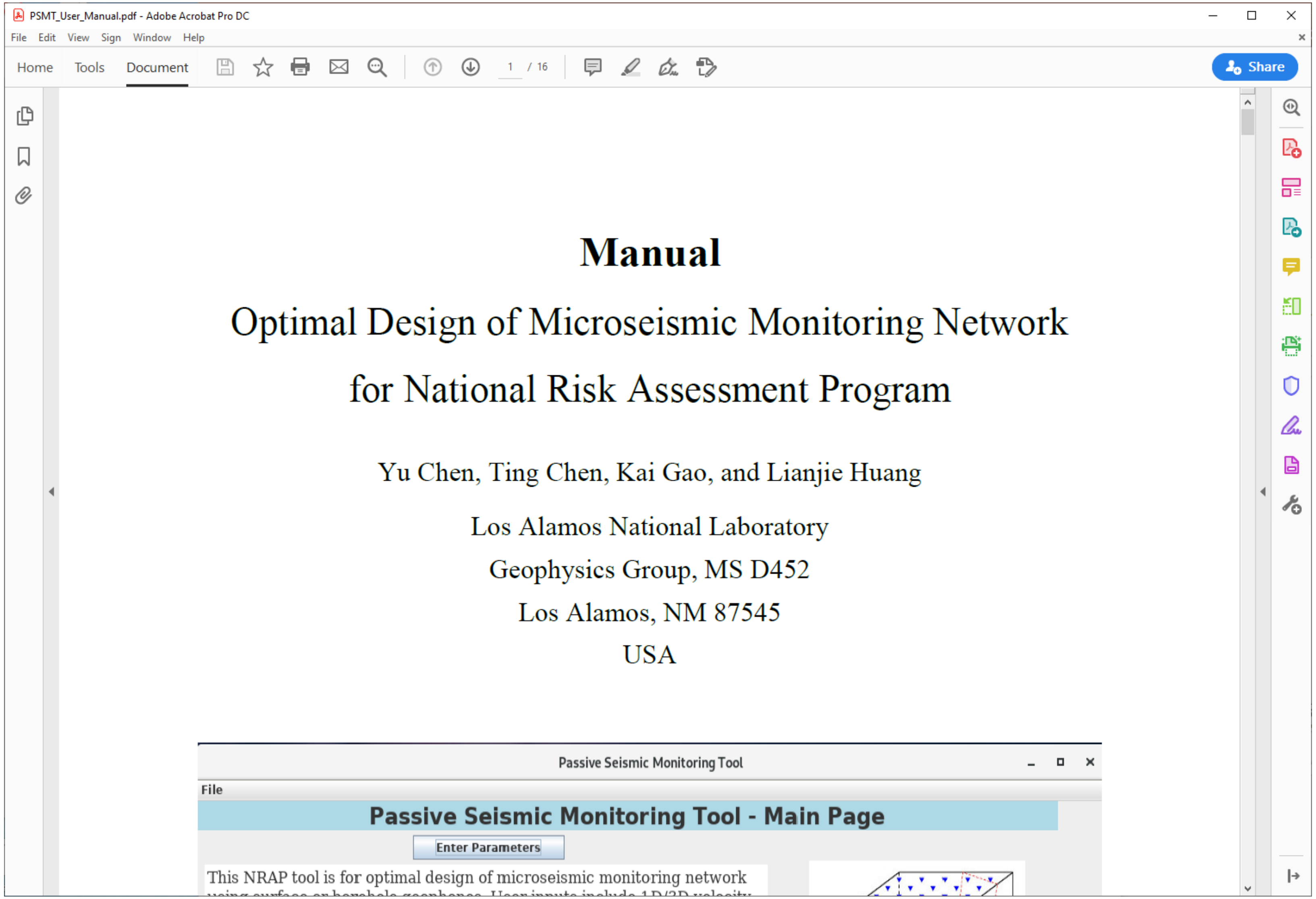


NRAP Tool

- The GUI of the NRAP tool is designed by MATRIC | Mid-Atlantic Technology, Research & Innovation Center, with executable files from LANL
- Tool can be run on Linux, Windows, and Mac Oss
- GUI is based on java
- java -jar ./NRAP_PSMT.jar
- Acknowledgments
- References
- User Manual



NRAP Tool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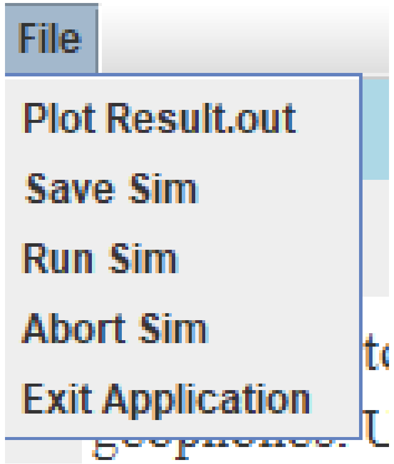
Manual
Optimal Design of Microseismic Monitoring Network
for National Risk Assessment Program
Yu Chen, Ting Chen, Kai Gao, and Lianjie Huang
Los Alamos National Laboratory
Geophysics Group, MS D452
Los Alamos, NM 87545
USA
Passive Seismic Monitoring Tool
File
Passive Seismic Monitoring Tool - Main Page
Enter Parameters
This NRAP tool is for optimal design of microseismic monitoring network

NRAP Tool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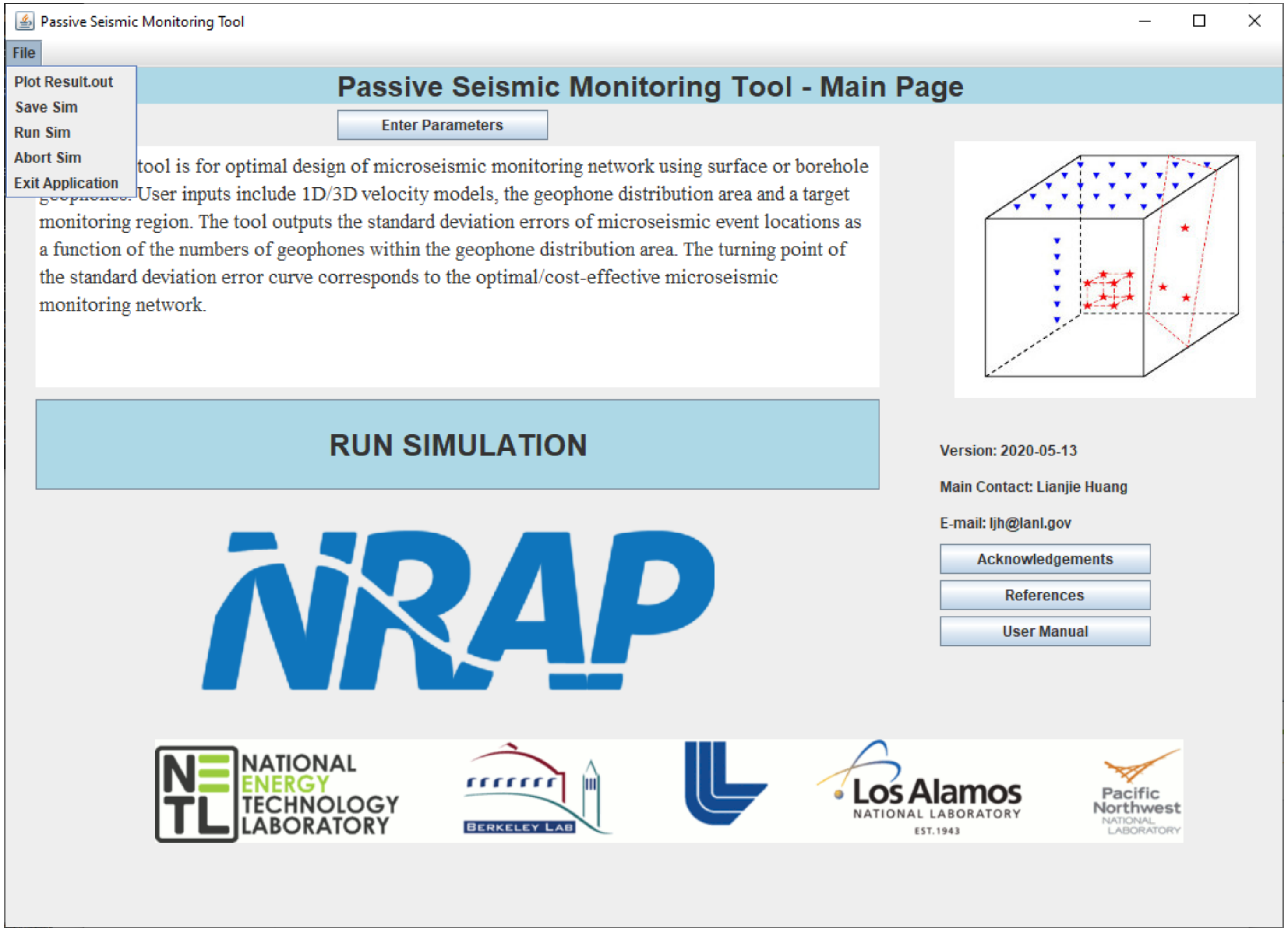
Passive Seismic Monitoring Tool
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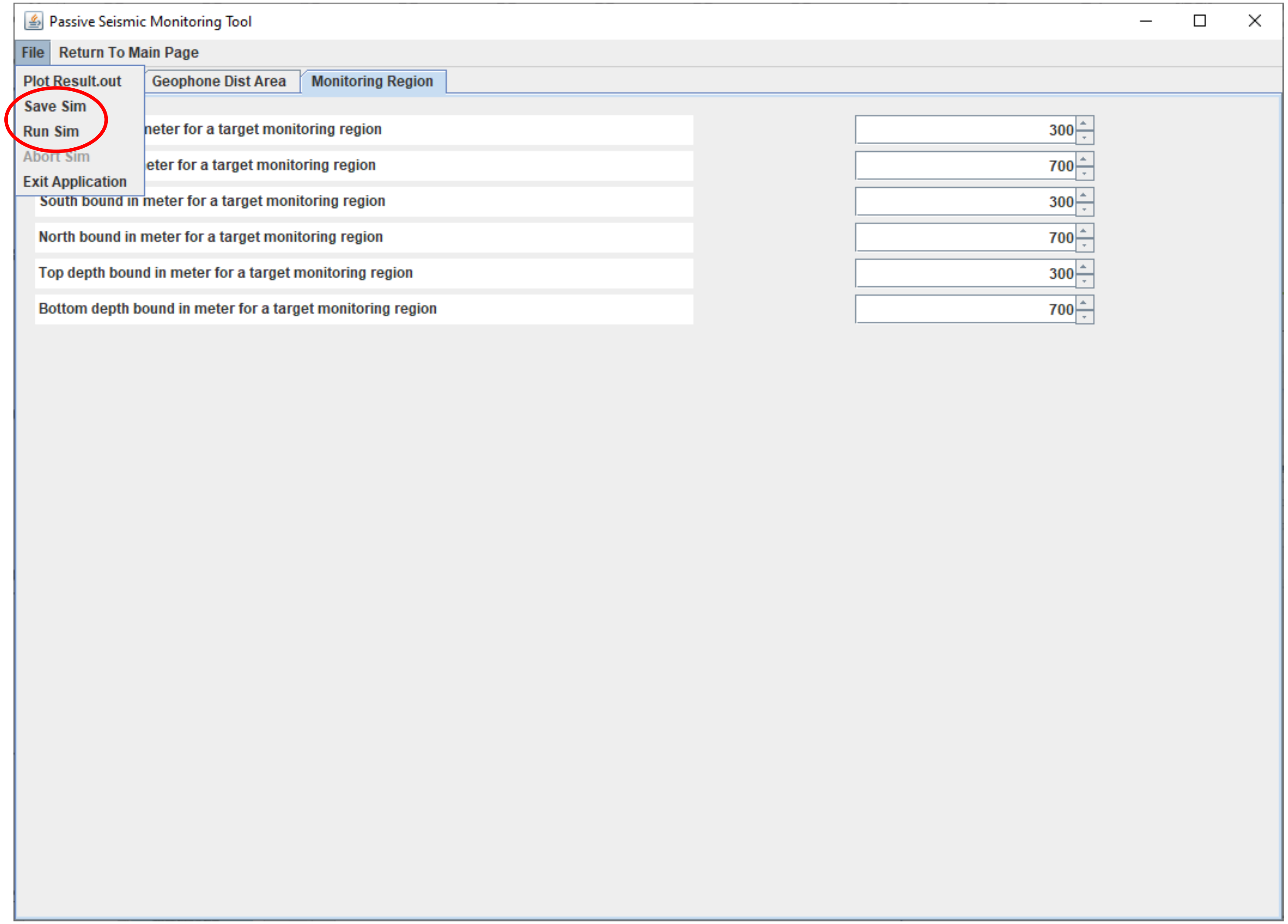
Plot Result.out
Save Sim
Run Sim
Abort Sim
Exit Application
Passive Seismic Monitoring Tool - Main Page
Enter Parameters
tool is for optimal design of microseismic monitoring network using surface or borehole
User inputs include 1D/3D velocity models, the geophone distribution area and a target
monitoring region. The tool outputs the standard deviation errors of microseismic event locations as
a function of the numbers of geophones within the geophone distribution area. The turning point of
the standard deviation error curve corresponds to the optimal/cost-effective microseismic
monitoring network.
RUN SIMULATION
Version: 2020-05-13
Main Contact: Lianjie Huang
E-mail: ljh@lanl.gov
Acknowledgements
References
User Manual
NRAP
NATIONAL ENERGY TECHNOLOGY LABORATORY
BERKELEY LAB
Los Alamos NATIONAL LABORATORY EST.1943
Pacific Northwest NATIONAL LABORATORY

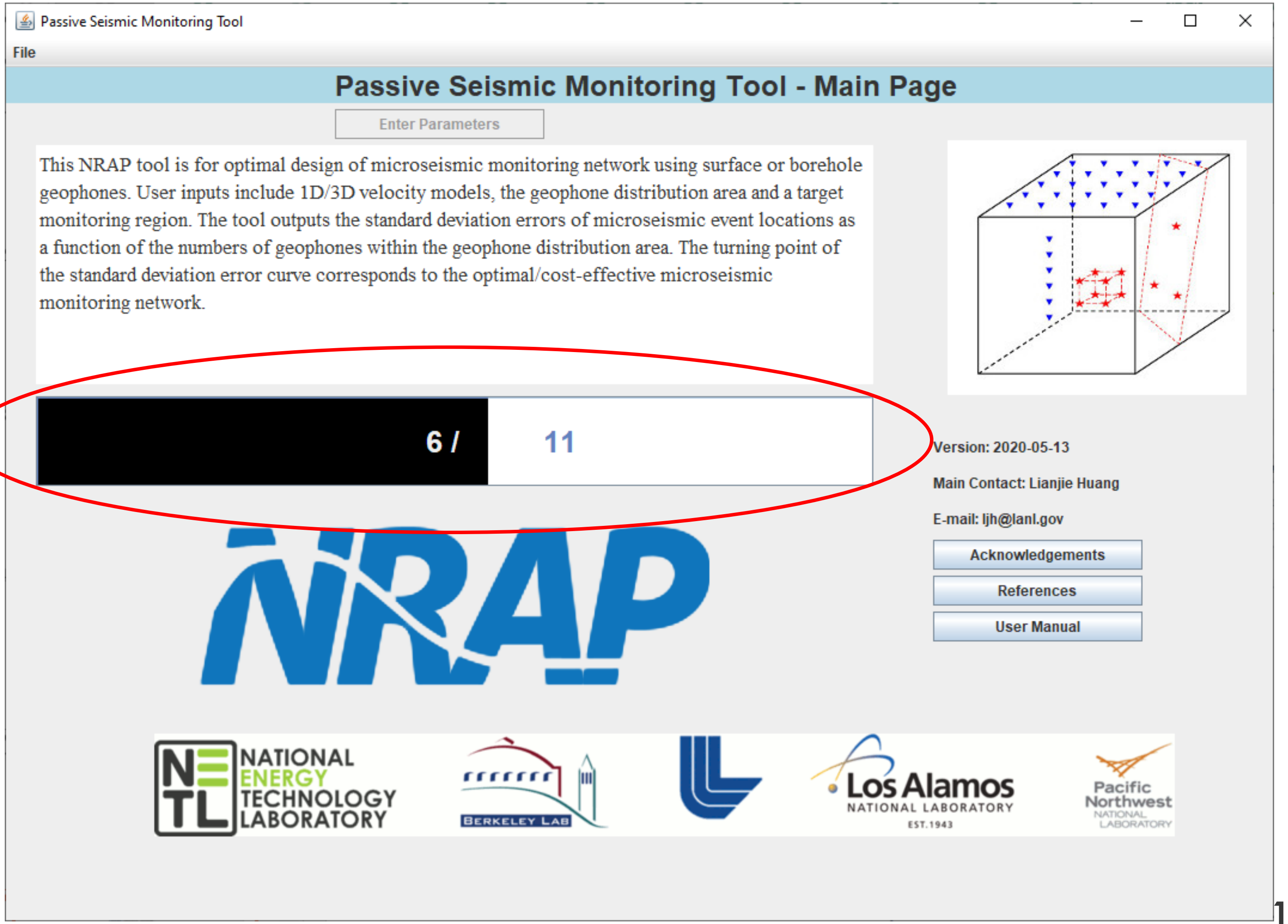
NRAP Tool

- Enter parameters
  - Define geophone distribution area, such as the surface area or borehole(s)
  - Define target monitoring region(s)
- Save parameters (Save Sim)
- Run simulation (Run Sim)



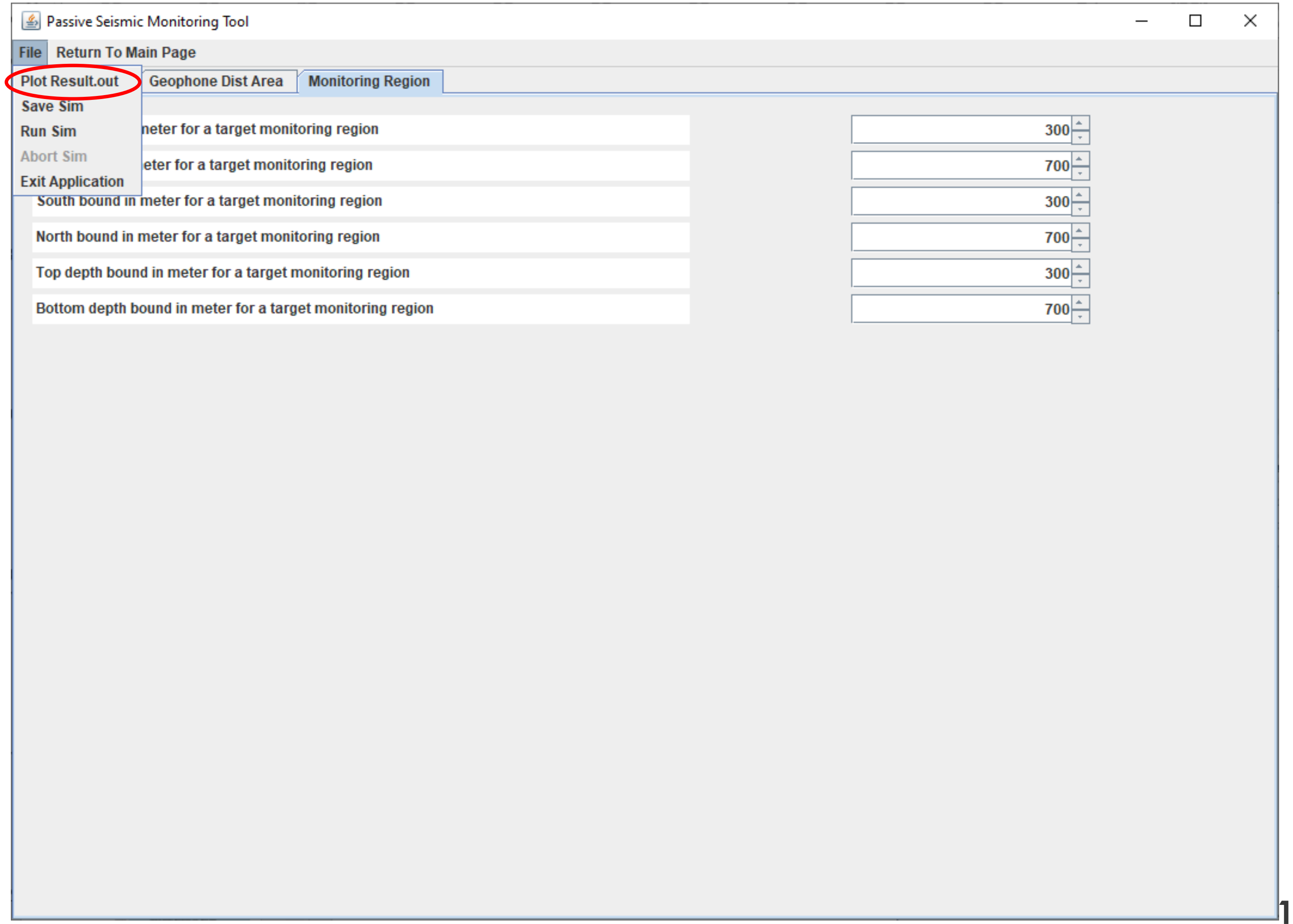
NRAP Tool

- Enter parameters
  - Define geophone distribution area, such as the surface area or borehole(s)
  - Define target monitoring region(s)
- Save parameters (Save Sim)
- Run simulation (Run Sim)
- Progress bar shows the job progress



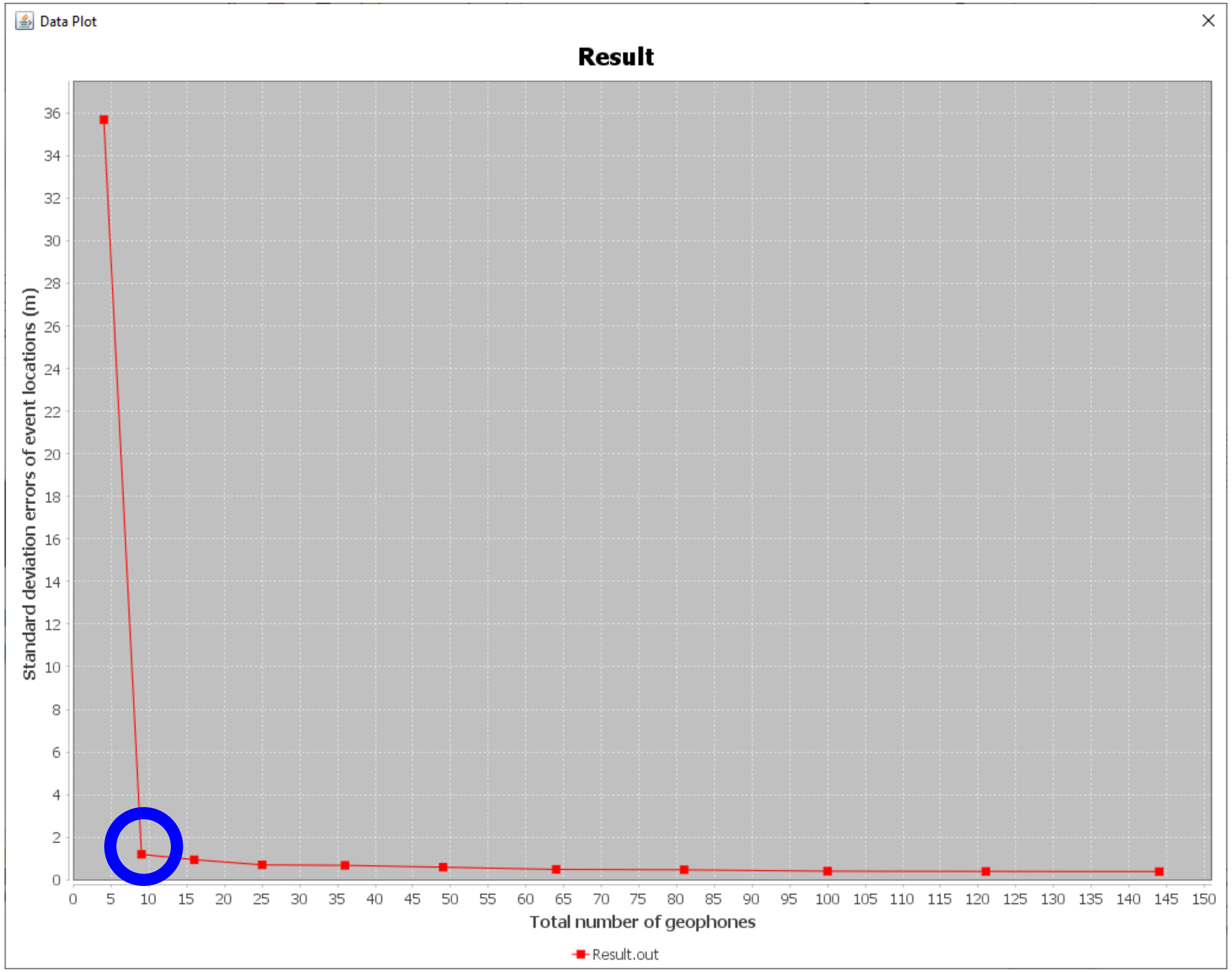
NRAP Tool

- Plot result (Result is automatically plotted after the job is completed.)



NRAP Tool

- Result of the three-layer model
  - Eight surface seismic stations are needed for cost-effective microseismic monitoring



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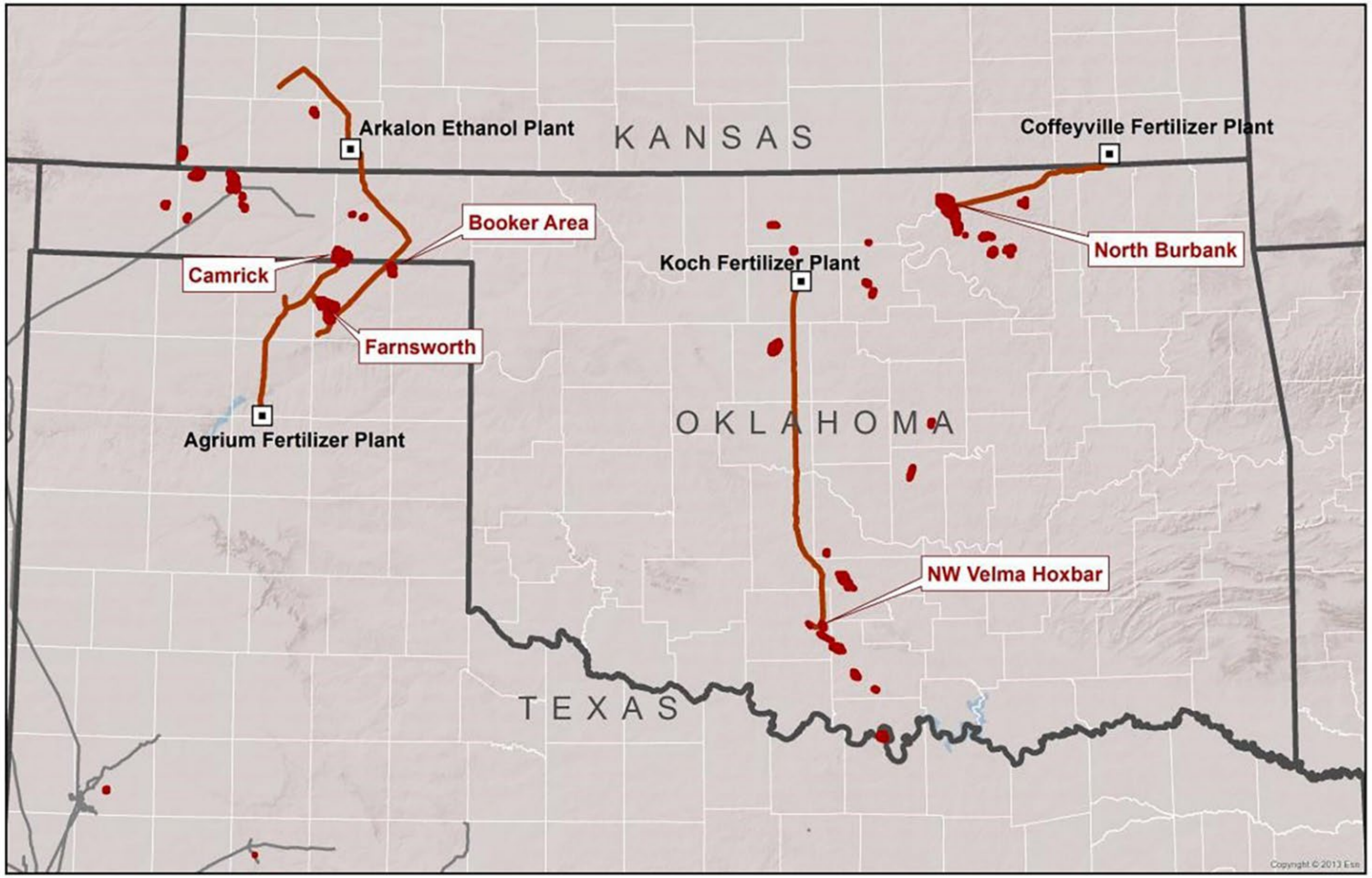
Farnsworth CO_2-EOR Field: SWP Phase III

(From: https://www.netl.doe.gov/coal/carbon-storage/atlas/swp/phase-III/farnsworth)



KEY PARAMETERS FOR FARNSWORTH UNIT

Depth: ~7,750 TD

Thickness: ~6.9 meters (~22.5 feet)

Porosity: ~15%

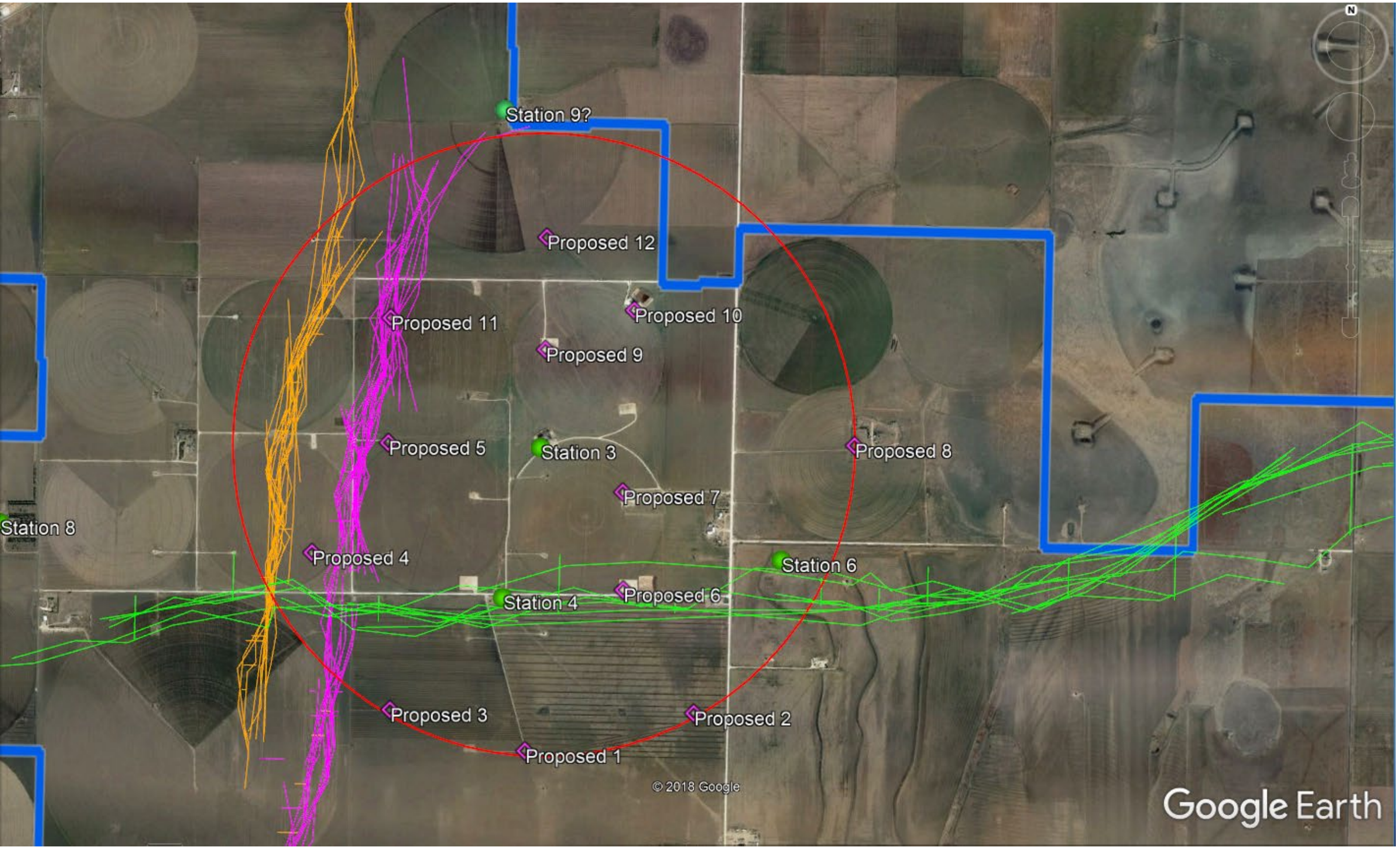
Permeability: ~65 mD, but highly variable

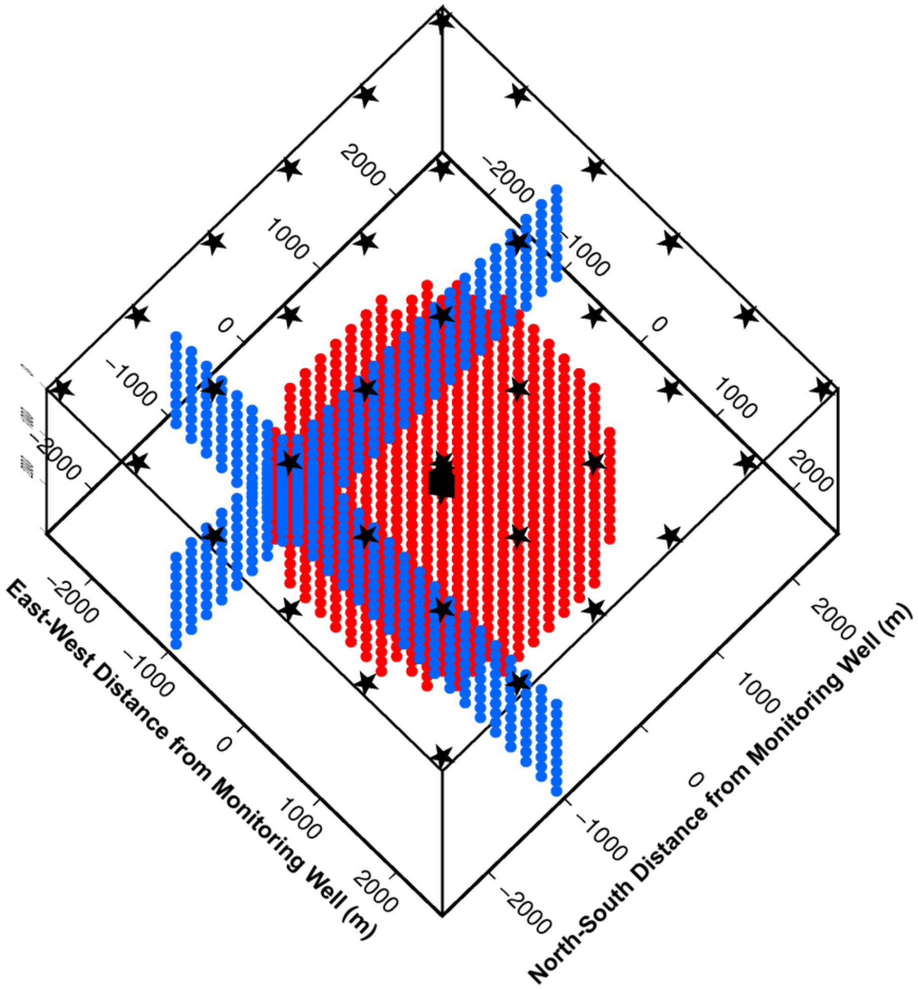
Pressure: ~4,200 psi

Temperature: ~168°F

Oil API: ~406

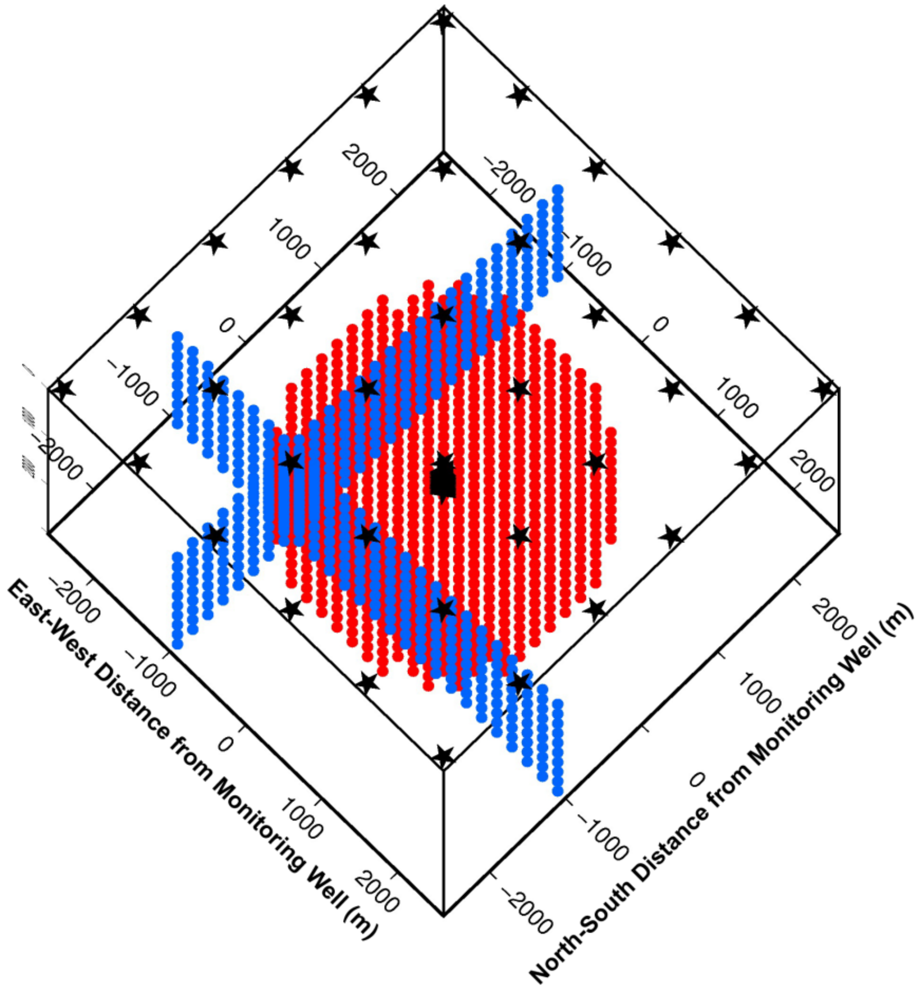
Target monitoring regions





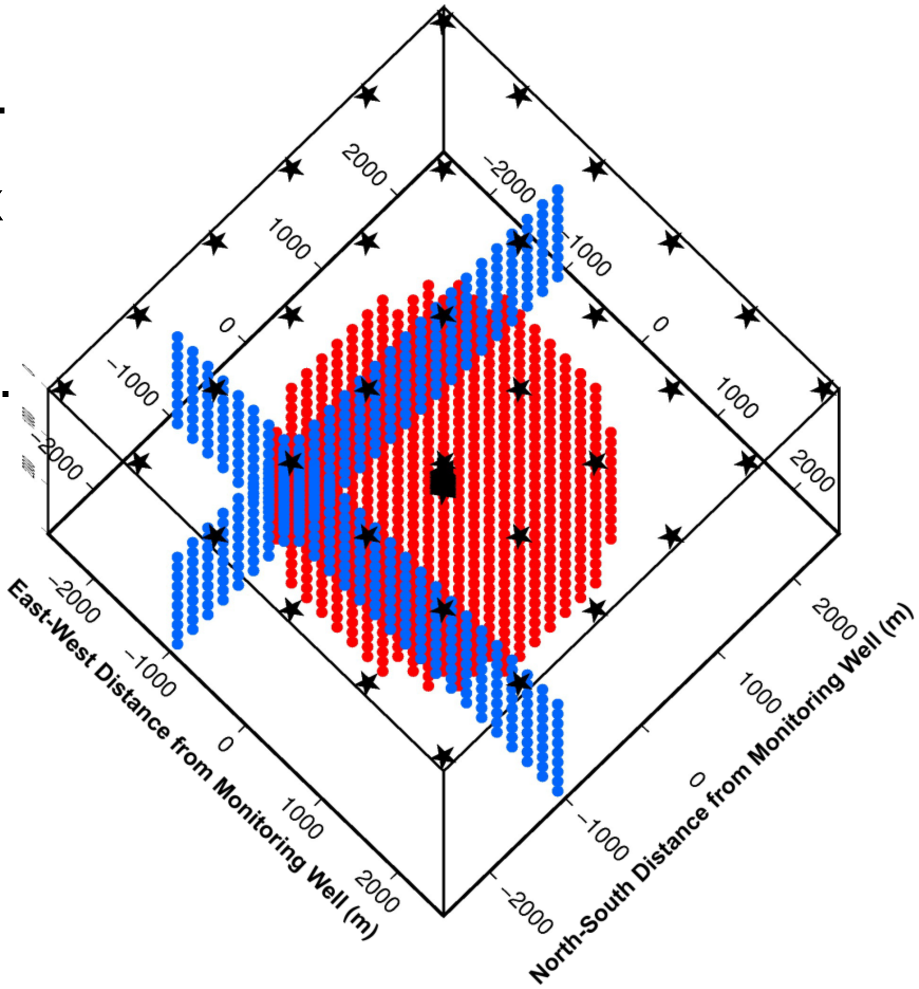
Target monitoring regions

- Reservoir: Cylinder region around the injection well: Radius of 1.6 km from the monitoring well; Depth range between 1.2 km and 3.0 km.
- Faults: 5 km long; Depth range between 1.2 km and 3.0 km.
- We design synthetic microseismic events with an interval of 0.2 km for the reservoir and 0.2 km for the faults.
- There are 1737 synthetic events (red) in the reservoir volume and 520 synthetic events (blue) along the faults.
- We invert locations and focal mechanisms of synthetic events, and compute standard deviation errors of locations between synthetic events and inverted events.

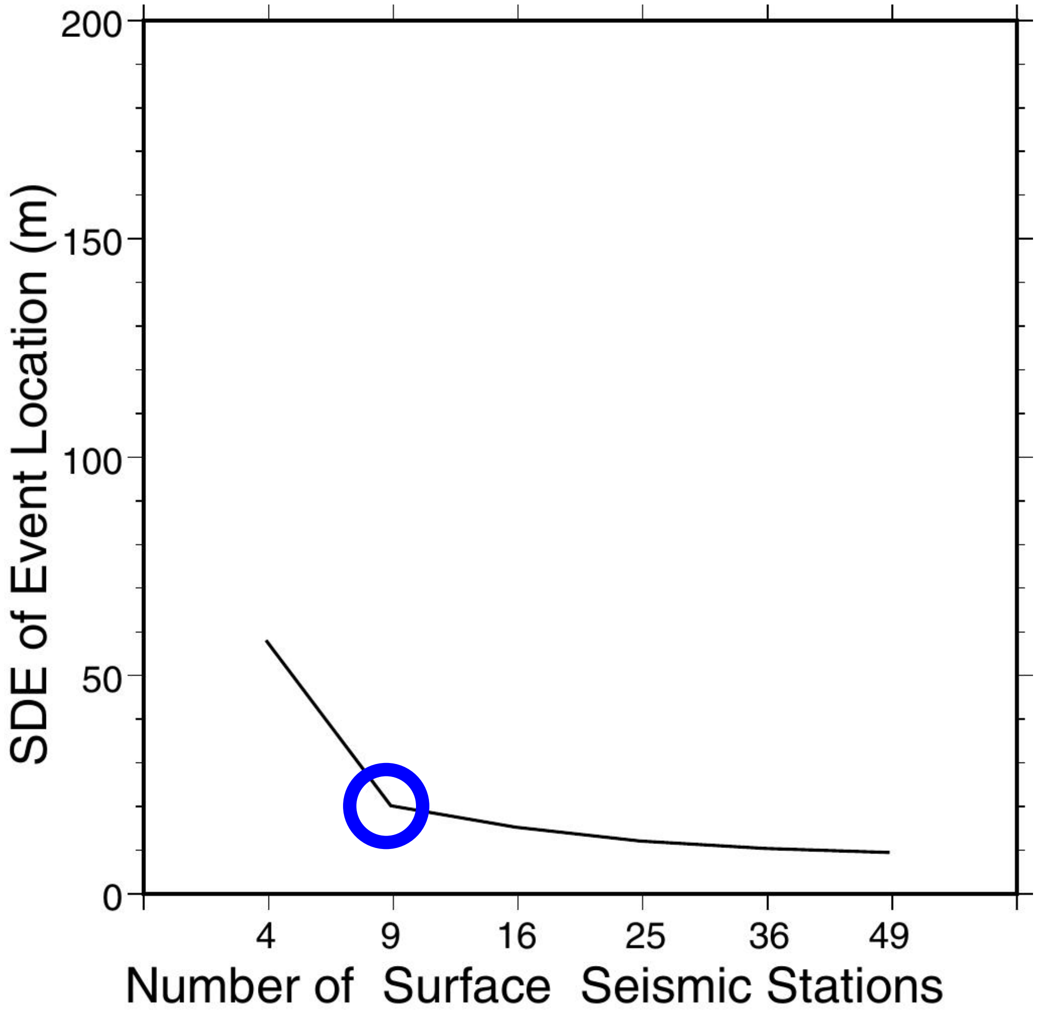


Surface network design

- Surface seismic stations within a square area of 5 km x 5 km.
- N x N surface geophones are evenly distributed in the 5 km x 5 km area.
- N is from 2 to 7, corresponding to 4 to 49 surface geophones.
- Standard deviation error of traveltime picks/velocity errors is 25 ms. Assume a normal distribution of the errors.

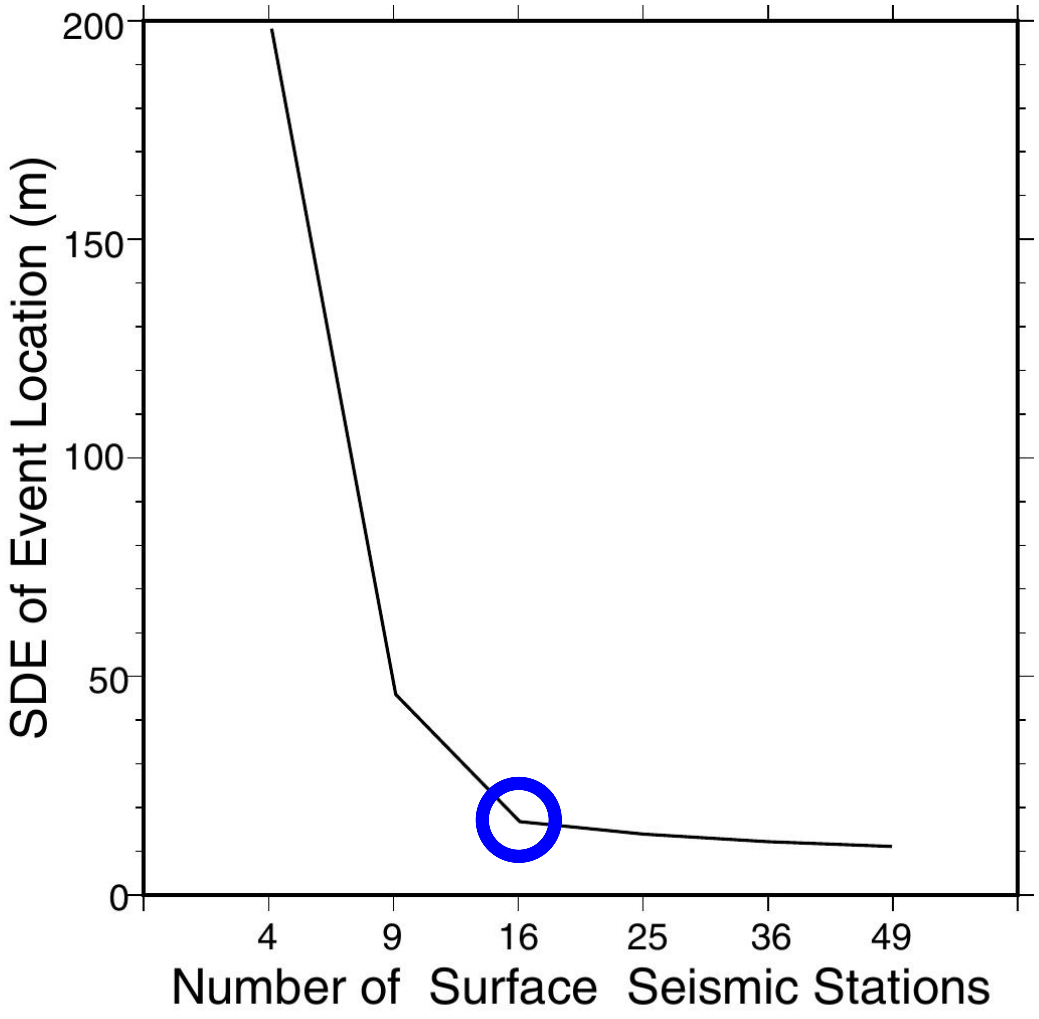


Location SDE (Monitoring storage reservoir)



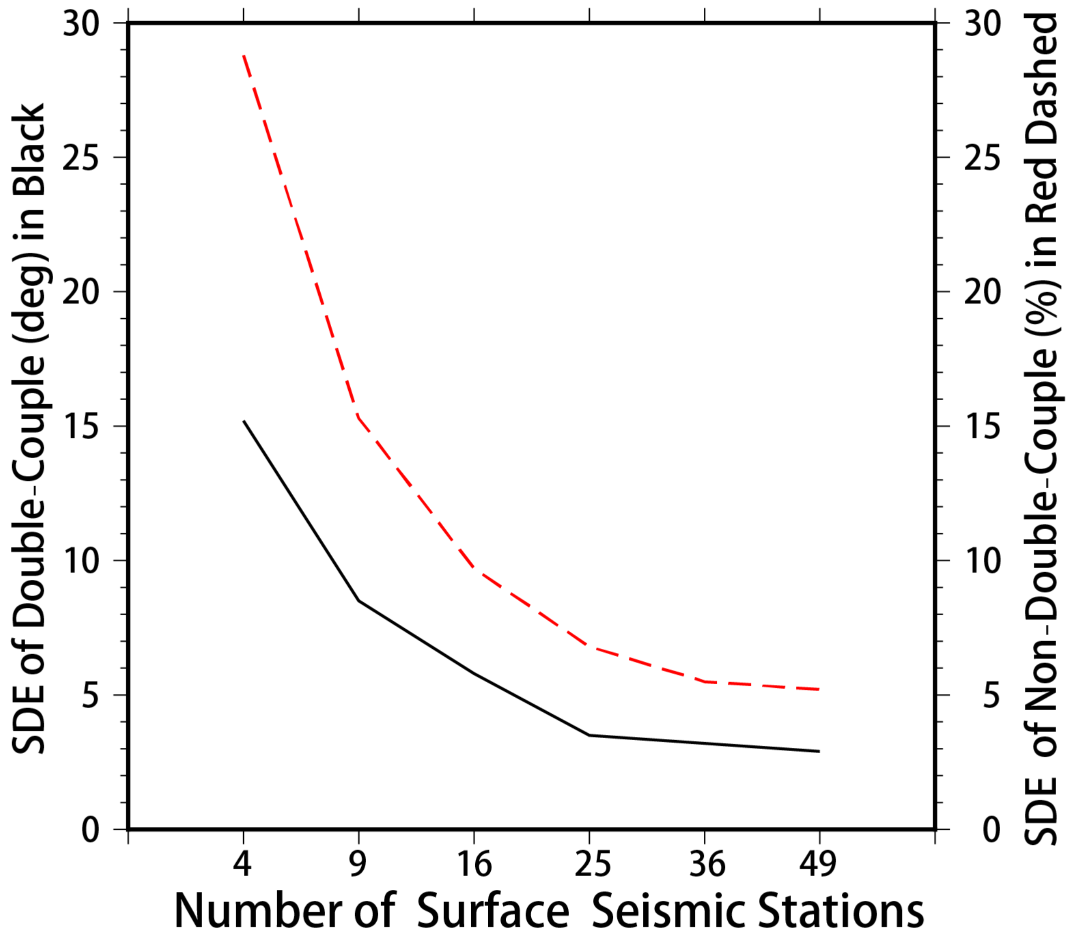
- 9 surface seismic receivers are needed for microseismic event location in the reservoir.
- Standard deviation error (SDE) is approximately 21 m for 9 surface stations and 16.1 m for 16 stations.

Location SDE (Monitoring faults)



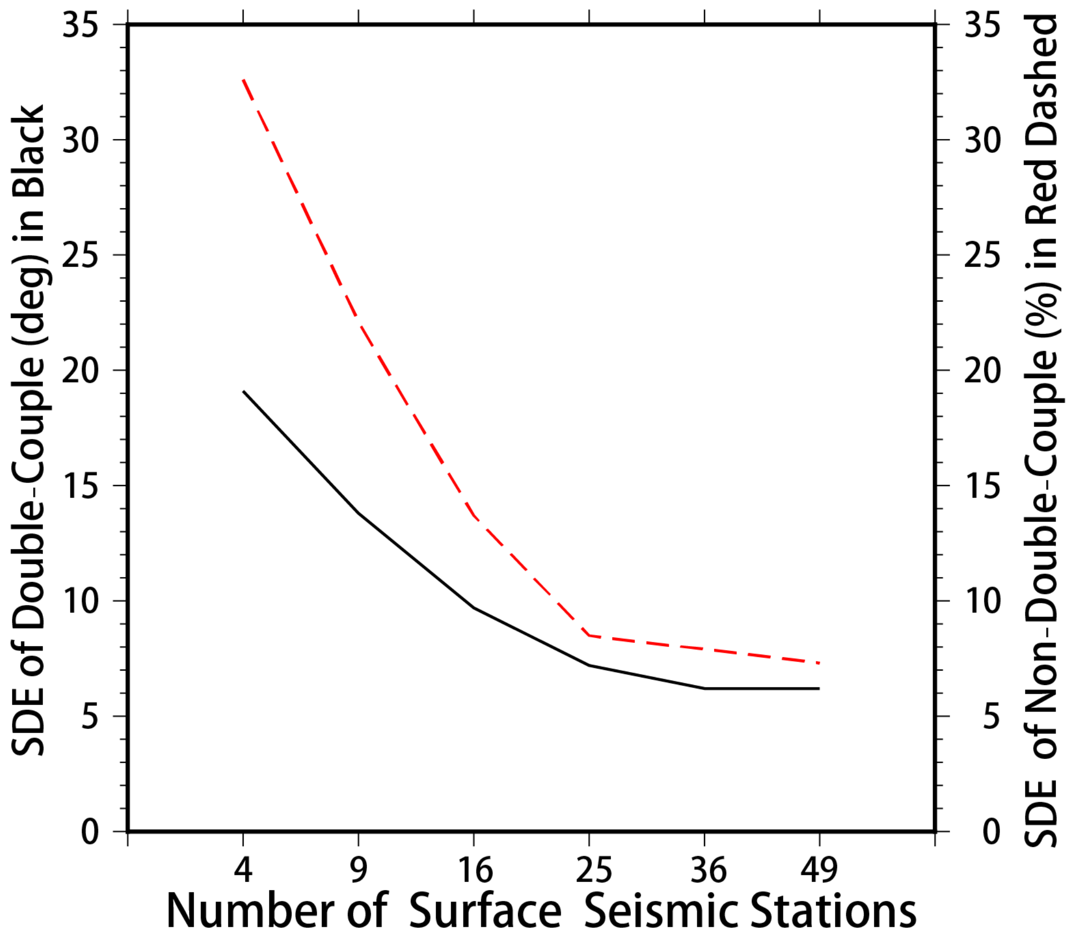
- 16 surface seismic receivers are needed for microseismic event location along the faults.
- Standard deviation error is approximately 17.5 m.

Focal mechanism SDE (Reservoir)



- 25 surface seismic receivers are needed for focal mechanism inversion of microseismic events in the reservoir.
- Standard deviation errors are approximately 4 deg for double-couple component and 5 % for non-double-couple component.
- The black solid curve and the dashed-red curve are for noise-free and noisy data in each panel

Focal mechanism SDE (Faults)



- 25 surface seismic receivers are needed for focal mechanism inversion of microseismic events along the faults.
- Standard deviation errors are approximately 7 deg for double-couple component and 9 % for non-double-couple component.
- The black solid curve and the dashed-red curve are for noise-free and noisy data in each panel

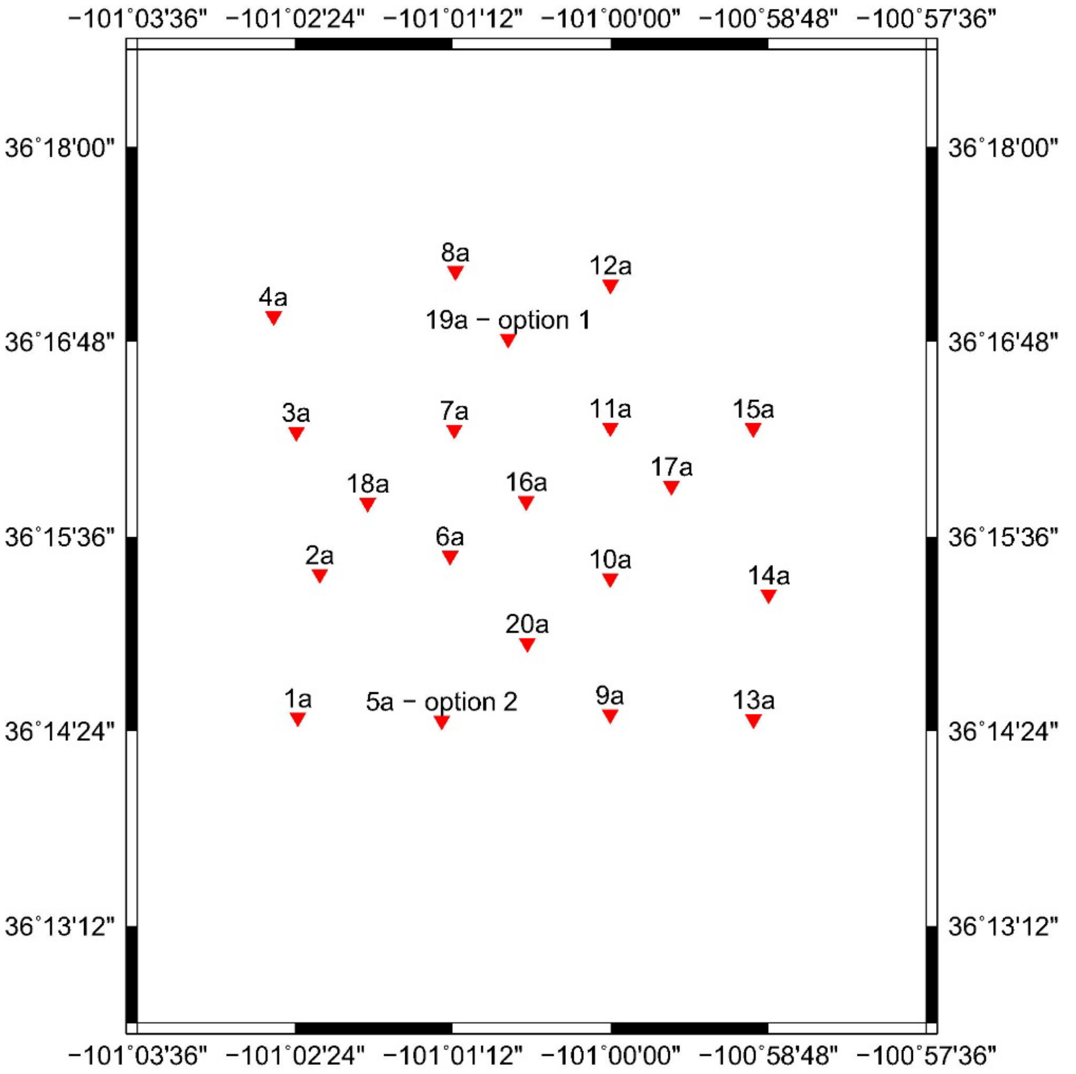
Locations of 25 seismic stations

No.	X(m)	Y(m)	Lon(deg)	Lat(deg)
1	-2.50	-2.50	-101.038640	36.241077
2	-2.50	-1.25	-101.038640	36.252339
3	-2.50	0.00	-101.038640	36.263600
4	-2.50	1.25	-101.038640	36.274861
5	-2.50	2.50	-101.038640	36.286123
6	-1.25	-2.50	-101.024674	36.241077
7	-1.25	-1.25	-101.024674	36.252339
8	-1.25	0.00	-101.024674	36.263600
9	-1.25	1.25	-101.024674	36.274861
10	-1.25	2.50	-101.024674	36.286123
11	0.00	-2.50	-101.010707	36.241077
12	0.00	-1.25	-101.010707	36.252339
13	0.00	0.00	-101.010707	36.263600
14	0.00	1.25	-101.010707	36.274861
15	0.00	2.50	-101.010707	36.286123
16	1.25	-2.50	-100.996740	36.241077
17	1.25	-1.25	-100.996740	36.252339
18	1.25	0.00	-100.996740	36.263600
19	1.25	1.25	-100.996740	36.274861
20	1.25	2.50	-100.996740	36.286123
21	2.50	-2.50	-100.982774	36.241077
22	2.50	-1.25	-100.982774	36.252339
23	2.50	0.00	-100.982774	36.263600
24	2.50	1.25	-100.982774	36.274861
25	2.50	2.50	-100.982774	36.286123

Updated with a given geophone distribution

Standard Deviation Errors (SDE) for the scenario in the figure on the right:

- SDE of event location for the reservoir: 15.5 m
- SDE of event location for the two faults: 17.2 m
- SDE of focal mechanism for the reservoir: 5 degree (DC); 7% (Non-DC)
- SDE of focal mechanism for the two faults: 7 degree (DC); 10% (Non-DC)



Summary

- An NRAP tool for optimal design of microseismic monitoring network is available at NETL EDX for geologic carbon storage and other microseismic monitoring applications: https://edx.netl.doe.gov/user/register.
  - Adaptively define the target monitoring region(s) based on site characterization, CO_2 plume migration, and early detection of induced microseismic events for detailed monitoring
  - Place geophones at different locations during different stages of geologic carbon storage (during CO_2 injection, post injection)
- The example application of the NRAP tool to the Farnsworth CO_2-EOR field shows that
  - 9 surface seismic stations are needed for microseismic event location in the reservoir, and 16 surface seismic stations are need for monitoring microseismic events in the faults.
  - 25 surface seismic receivers are needed for focal mechanism inversion of microseismic events in the reservoir and the faults (this capability is not included in the current release of the tool).

Thank you!

Comments and Questions:

NRAP@NETL.doe.gov

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