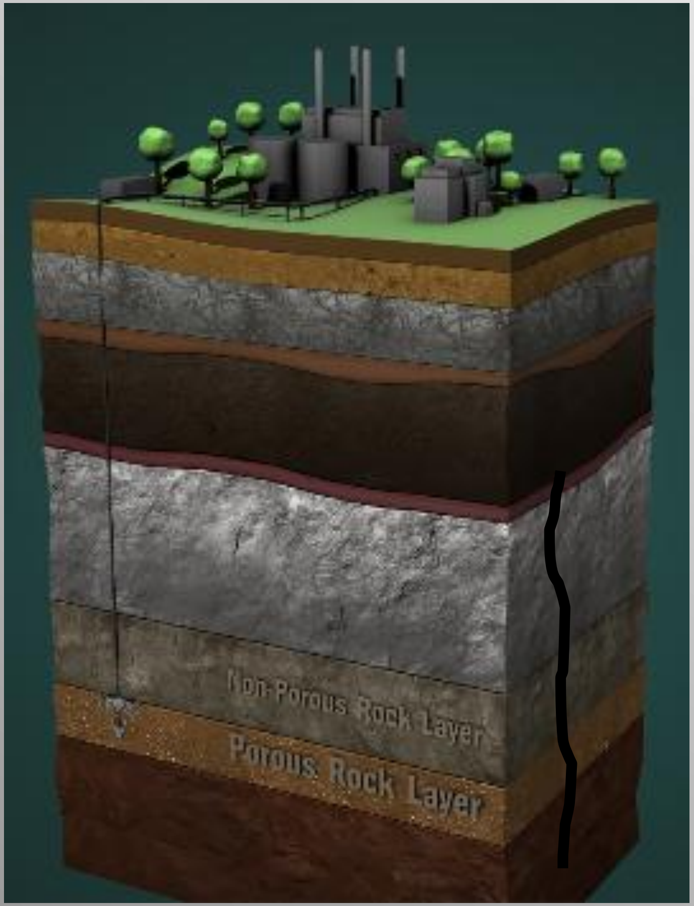


NRAP Tools for Assessment of Carbon Storage Risk Performance: Supporting Decision Making Amidst Uncertainty

- ***Ground Motion Prediction applications to potential Induced Seismicity (GMPIS)***
- ***Multiple Source Leakage ROM (MSLR)***

NRAP Phase I Tools Webinar Series
webinar; June 20, 2016

NETL | Berkeley Lab | Los Alamos National Laboratory EST.1943 | Pacific Northwest National Laboratory

NRAP National Risk Assessment Partnership

U.S. Department of Energy | National Energy Technology Laboratory

National Risk Assessment Partnership

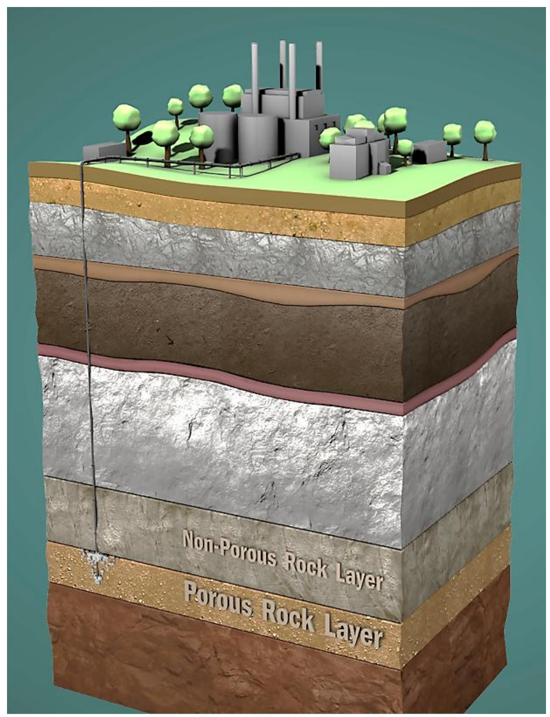
NRAP leverages DOE's capabilities to help quantify uncertainties and risks necessary to remove barriers to full-scale CO_2 storage deployment.

Building toolsets and improving the science base to address…

- Potential impacts related to release of CO_2 or brine from the storage reservoir
- Potential ground-motion impacts due to injection of CO_2

Technical Team

NETL
Berkeley Lab
Los Alamos National Laboratory EST. 1943
Pacific Northwest National Laboratory



Stakeholder Group

AEP American Electric Power
Blue Source
bp
EPA United States Environmental Protection Agency
ExxonMobil
ieaghg
IEc
MIT
NRDC
Schlumberger
Southern States Energy Board
Stanford University
Texas Railroad Commission
USGS
The University of Utah
Wade, LLC
Whiting
Zurich Because change happenz

Carbon Storage Program

MISSION

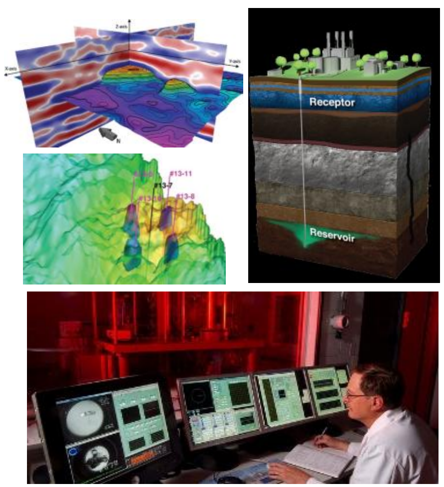
Ensure Permanence – Protect Environment – Facilitate Awareness – Improve Storage Efficiency – Commercial-Readiness by 2030

Program Approach & Technical Accomplishments

ADVANCED STORAGE

Monitoring, Verification, and Accounting

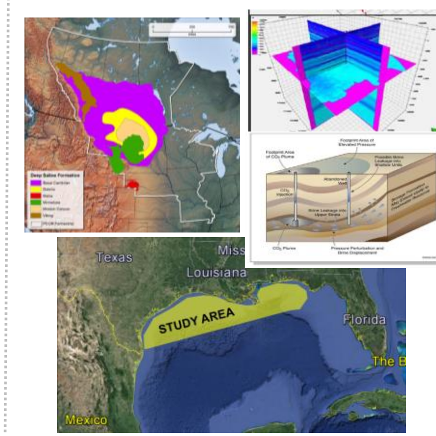
Geologic Storage, Simulation, and Risk Assessment



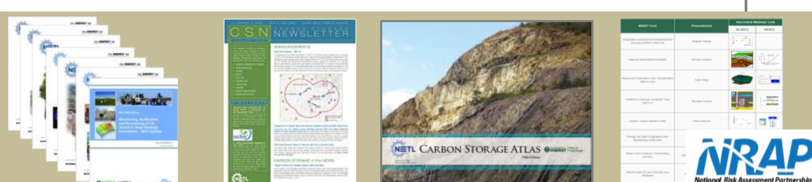
STORAGE INFRASTRUCTURE

Regional Carbon Sequestration Partnership Initiative

Onshore and Offshore Characterization and Brine Extraction Storage Tests (BEST)



Technology Transfer



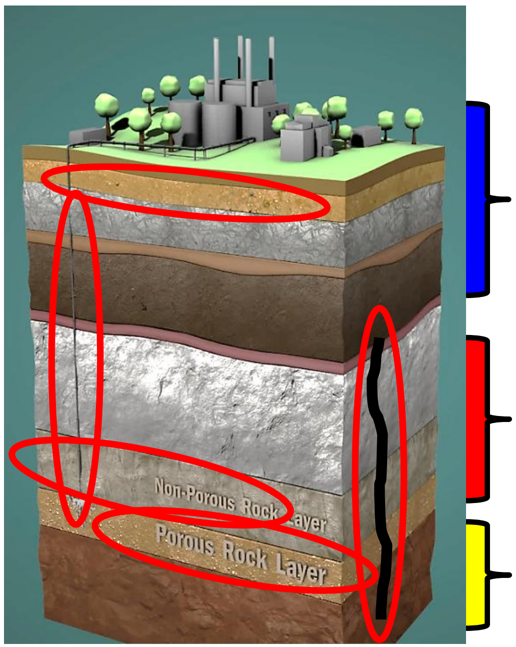
Please visit the Carbon Storage Program documents and reference materials at http://www.netl.doe.gov/research/coal/carbon-storage/publications

–NETL –Industry –Universities –National Labs–

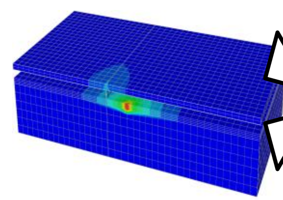
U.S. DEPARTMENT OF ENERGY | National Energy Technology Laboratory

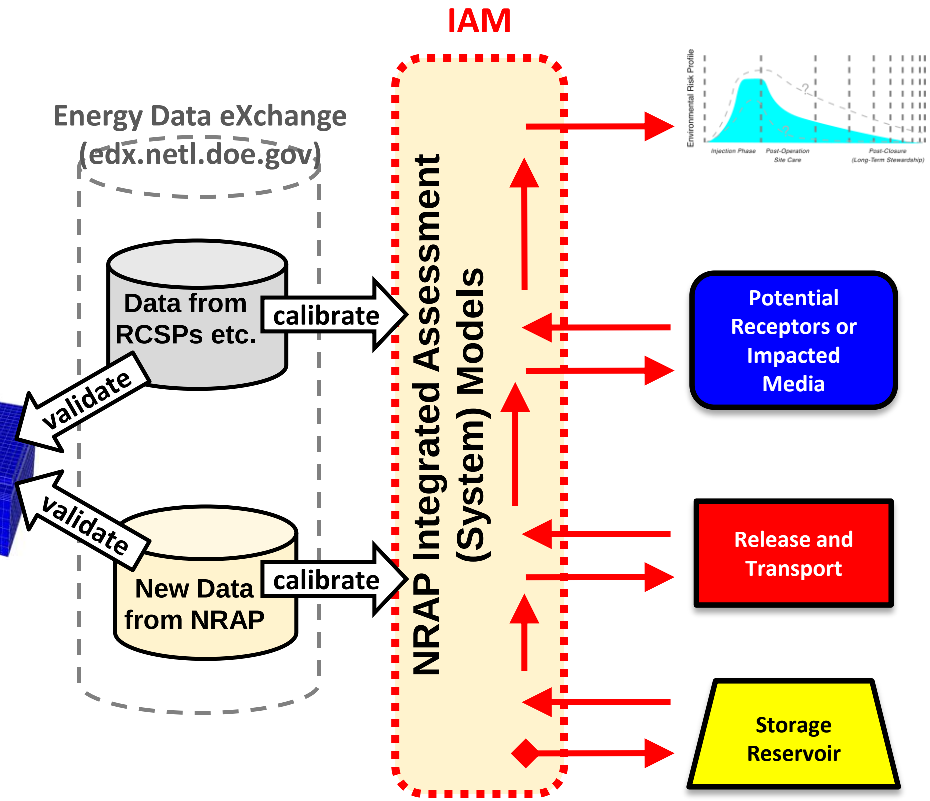
NRAP's approach to quantifying performance relies on reduced-order models to probe uncertainty in the system.

A. Divide system into discrete components



B. Develop detailed component models that are validated against lab/field data



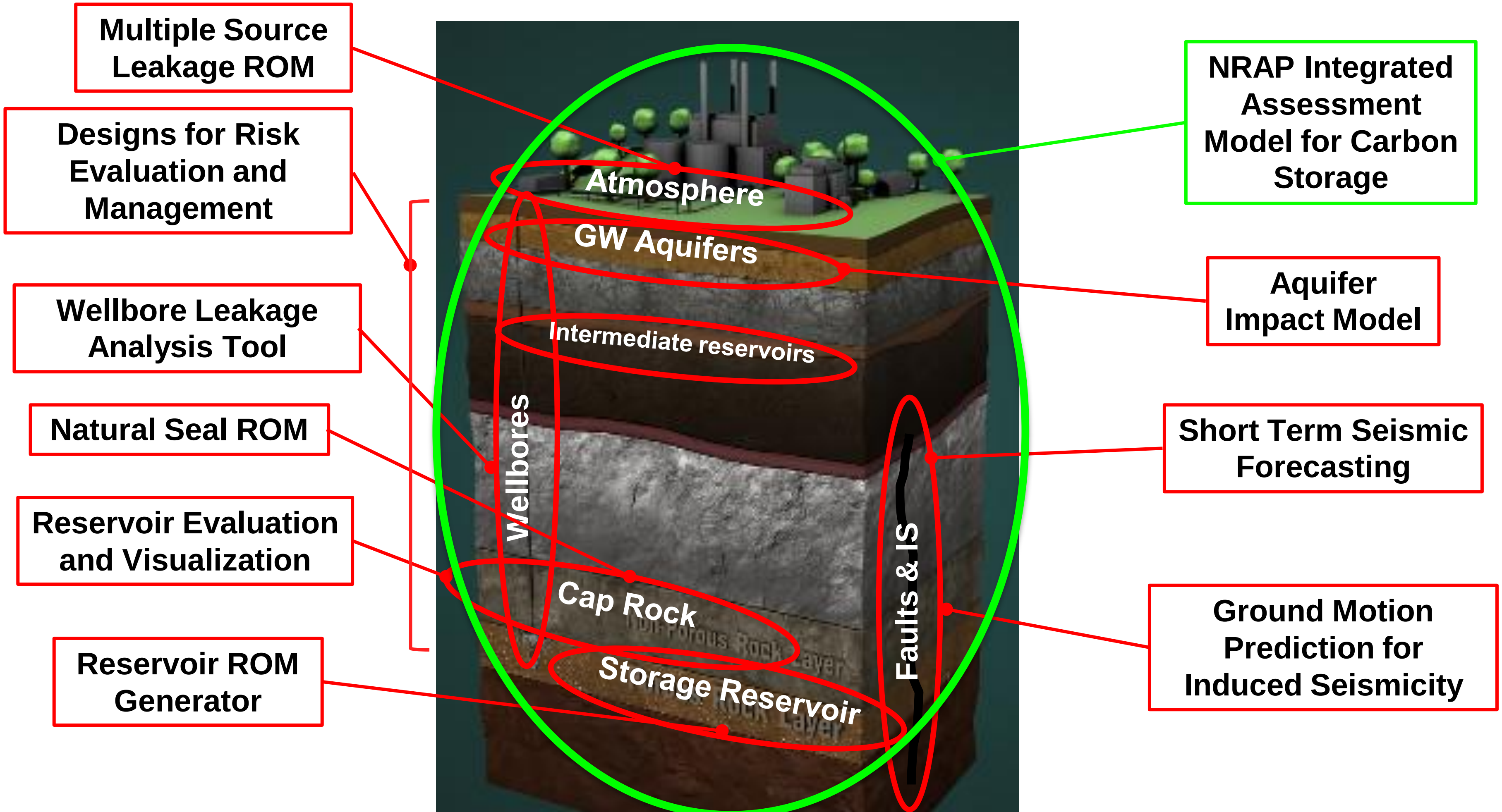


C. Develop reduced-order models (ROMs) that rapidly reproduce component model predictions

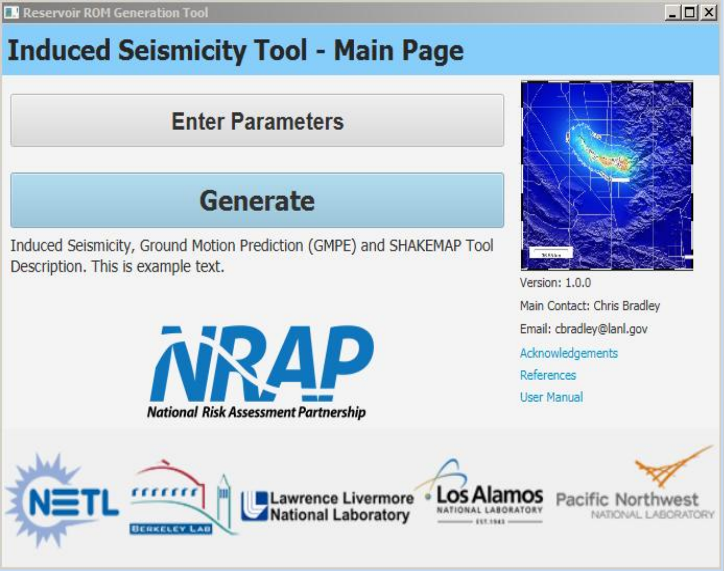
D. Link ROMs via integrated assessment models (IAMs) to predict system performance & risk; calibrate using lab/field data from NRAP and other sources

E. Develop strategic monitoring protocols that allow verification of predicted system performance

NRAP CO_2 Storage Risk Assessment Toolset



Tool Beta Testing Link:
www.edx.netl.doe.gov/nrap



NRAP Tool Webinar Series

Webinar

Ground Motion Prediction applications to potential Induced Seismicity (GMPIS) Tool

June 20, 2016

Chris Bradley,
David Coblentz,
Richard Lee

[1] Los Alamos National Laboratory; Los Alamos, NM

U.S. DEPARTMENT OF ENERGY | National Energy Technology Laboratory

GMPIS: Ground Motion Prediction applications to potential Induced Seismicity

- **Ground motion potential induced earthquakes based on global dataset**
  - System includes PGA and response spectral ground motion prediction of Magnitude 1-4 (M_w 1-4) earthquakes with site response corrections
- **System also includes prediction of ground motion from western U.S. tectonic earthquakes M_w 5-8) (developed by Pacific Earthquake Engineering Research center (PEER), NGA models)**
- **Straightforward capability to modify input for other site locations or incorporate more refined site parameters**

Background: Prediction of Ground Motion

- **Used Douglass et al. (2013) regressions for peak spectral parameters for shallow induced earthquakes occurring in Basel, Switzerland, Geysers, U.S., Hengill, Iceland, Roswinkel, Netherlands, Soultz, France and Voerendaal, Germany**
- **Processed nearly 4,000 records**
- **Ground motion prediction equations (GMPEs) were developed from raw and site-corrected data.**
- **Variability derived from the regressions is larger because the data for all site locations were combined to create the implemented GMPE.**
  - Variability in source, path and site accommodated in the GMPEs
- **GMPEs of Douglass et al. (2013) were reviewed, coded and checked**

Site Amplification Adjustments to GMPEs

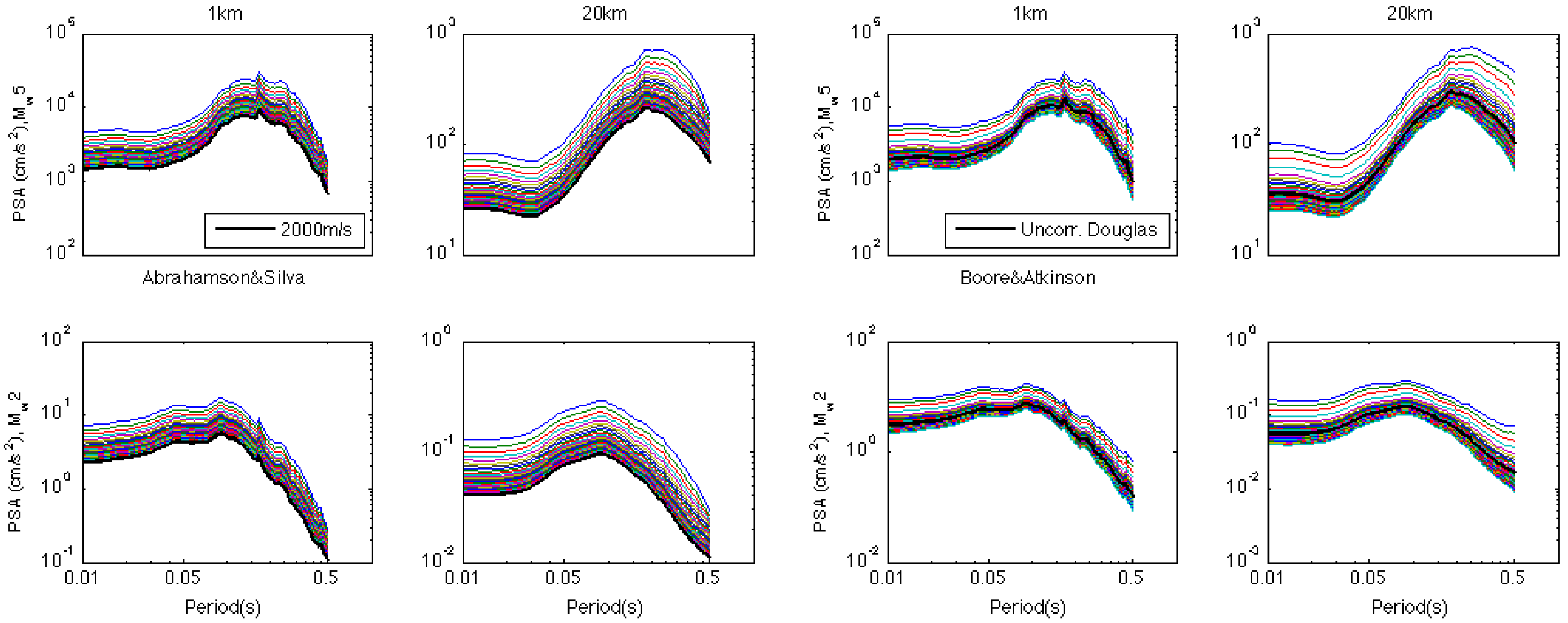
- **Douglass GMPEs were developed for a specified reference site condition (Vs = 1100 m/s)**
- **Because most potential sites have not been characterized, desire simple approach to capture site amplification**
- **Employs V_{S30} site amplification approach (mean shear-wave velocity over the first 30 m); much less sophisticated than a detailed engineering site characterization approach**
  - Approach does not reduce GMPE variance but may reduce site amplification bias
- **Two V_{S30} site amplification approaches were taken from the recent next generation attenuation (NGA) relationships**
- **For most sites, V_{S30} is unknown and cannot be directly inferred so proxy methods are used (incl. geology, topography)**

Site-specific Application and Calibration of IS GMPEs

- **Site V_{S30}**
  - Possible seismic borehole or other site geophysics to constrain V_{S30}
  - Inferred V_{S30} based on geology and/or topography
- **Future site-specific calibration**
  - Possible instrument deployment and monitoring of small induced seismic events could be used to calibrate GMPEs reducing bias in the median and possibly reducing variability
  - Uncertainty model could be developed for IS GMPE for uncertain or mixed site characterization models
  - Uncertainty model can be incorporated in PSHA logic tree

Site Amplification Adjustments to GMPEs (continued)

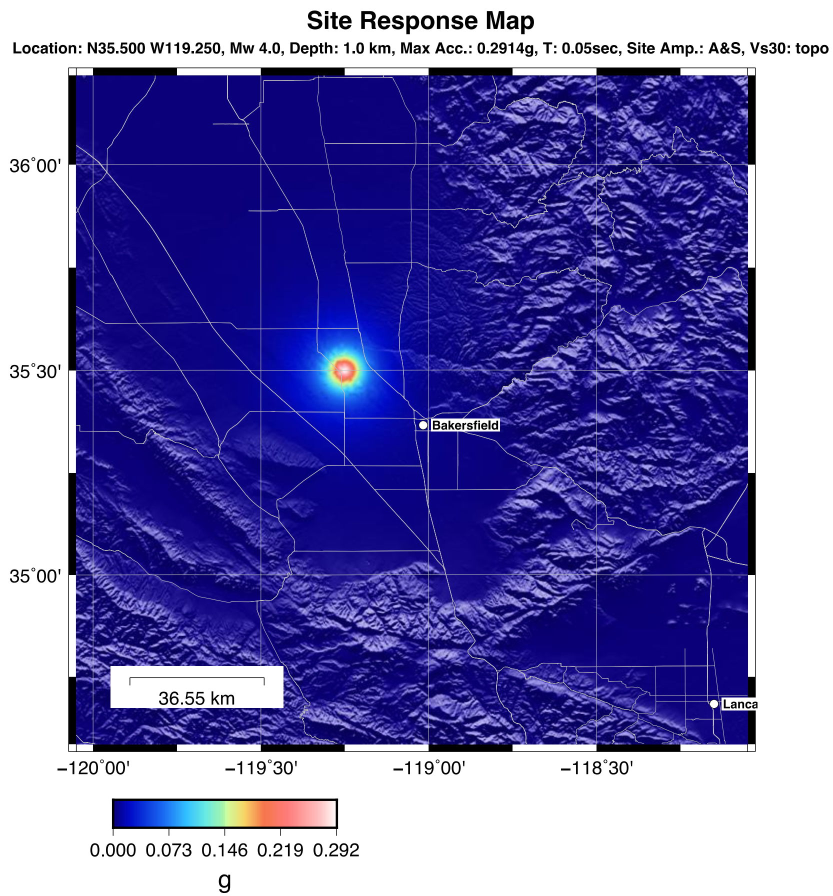
- **Current capability to estimate site amplifications corresponding to V_{S30} values ranging from 100-2000 m/s**



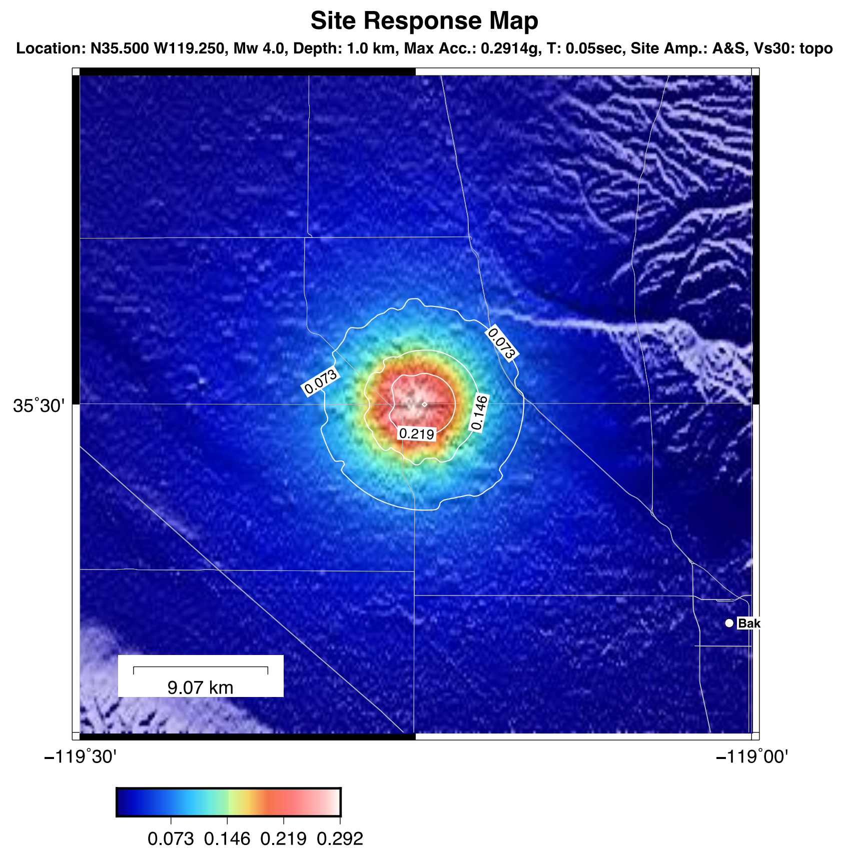
ShakeMap Capability

- GMPIS generates data for development of " ShakeMap" type ground motion maps
- GMT compatible files are created based on input spatial ground motion data, fault and geographic data.
- Using topographic proxy, ~190,000 V_{S30} sites evaluated for Kimberlina
- Default example provided for Kimberlina area assumes occurrence of both induced seismicity (M_w 4) near the Pond-Poso fault and a tectonic earthquake (M_w 6.7) rupturing the entire mapped length of the Pond-Poso fault (reverse fault w/ 60-deg, top of rupture 1-km deep, down-dip rupture width is 15 km)
- Illustration below is for the median 20-Hz 5% damped spectral acceleration map based on available fault data and V_{S30} topography proxy
- User can develop median, median + sigma ground motion maps for a range of 5% damped response spectral frequencies

Induced Seismic Event: Near the Pond-Poso Fault-median Ground Motions Predicted for a Hypothetical M_w 4.0 Earthquake

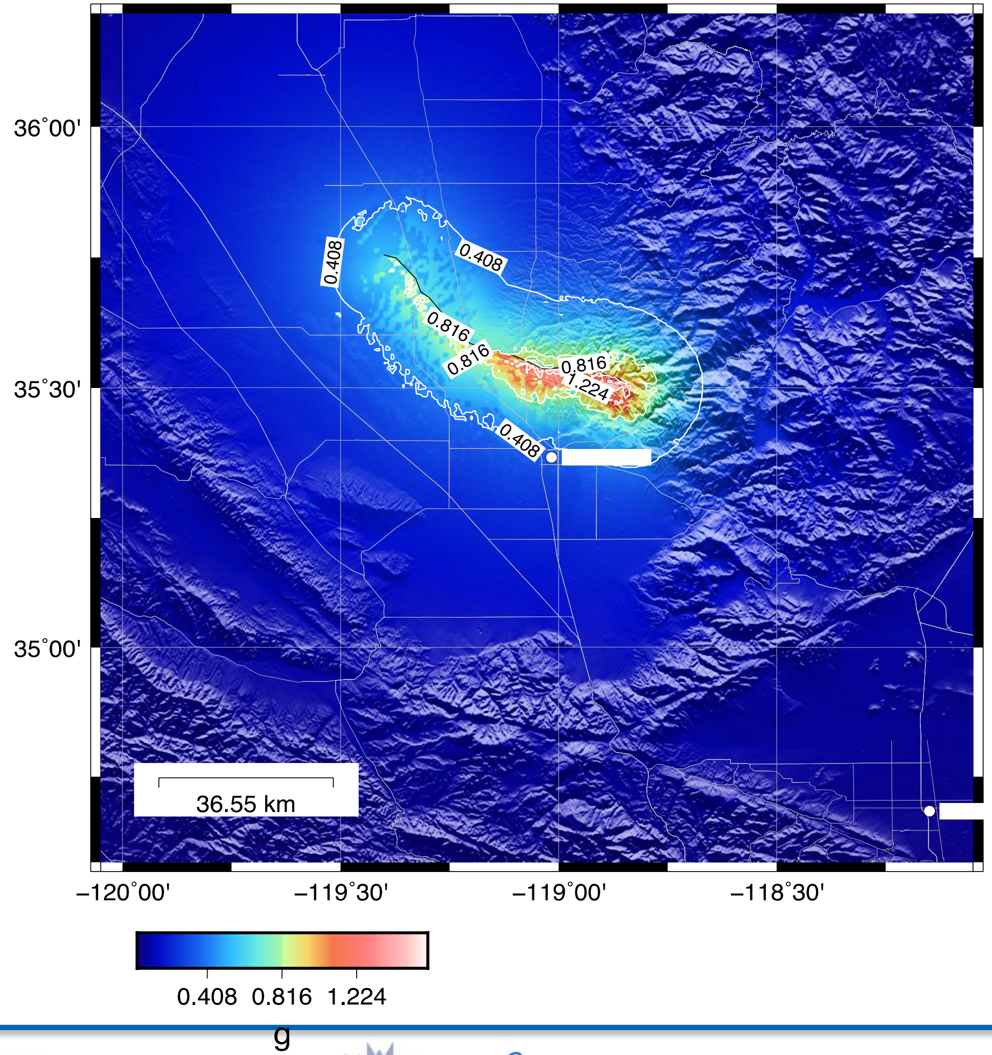


Map of Site response from an induced event In San Joaquin Valley



Large Scale Map of Site response showing the detail accelerations in Kimberlina area

Tectonic Event: Pond-Poso Fault- median ground motions predicted for a hypothetical M_w 6.7 earthquake



System Inputs

- **Selection for (1) induced event; (2) tectonic event; (3) both**
- **Induced event: location x, y, z (lat, long, km); M_w; V_{S30} option; 5% damped frequency; ground motion fractile**
- **Tectonic event: coordinates of fault (lat, long); dip; mechanism; M_w; V_{S30} option; 5% damped frequency**
- **Site response: location of site(s): lat, long; V_{S30} of site(s); depth to 2.5 km/sec horizon (tectonic event only; not currently supported)**
- **ShakeMap: input induced and/or tectonic ground motion for sites; output epicenter/fault data, Sa data for sites; title files**
- **GMT: input ShakeMap data above and topography, roads, cities/names; output map**

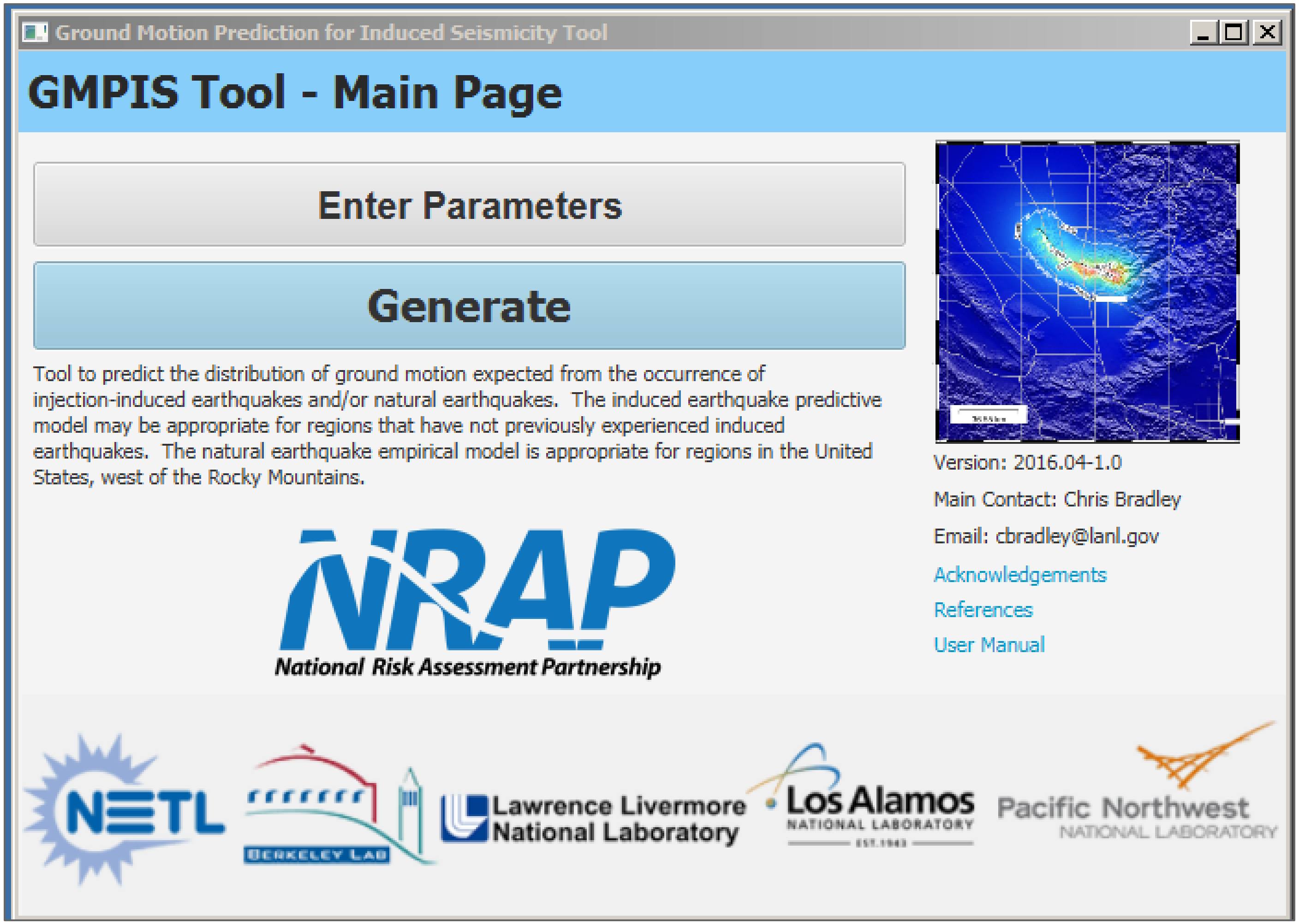
Application Flowchart

- Selection of assumed green-field site for injection.
- Start shallow site characterization program
- Preliminary evaluation of the potential occurrence of induced and tectonic earthquakes. Development of site-corrected induced and tectonic GMPEs for design
- Design and construction of facility (including seismic instrumentation)
- Operation of facility
- Potential onset of IS
- Calibrate IS GMPE and recurrence rate based on collected data
- If necessary revisit ground motion hazard and design basis
- If necessary, implement hazard mitigation plans (e.g., revised injection rates, depth of injection)

Introduction to GMPIS Tool

- **On the introduction page of the GUI, click on "Enter Parameters"**

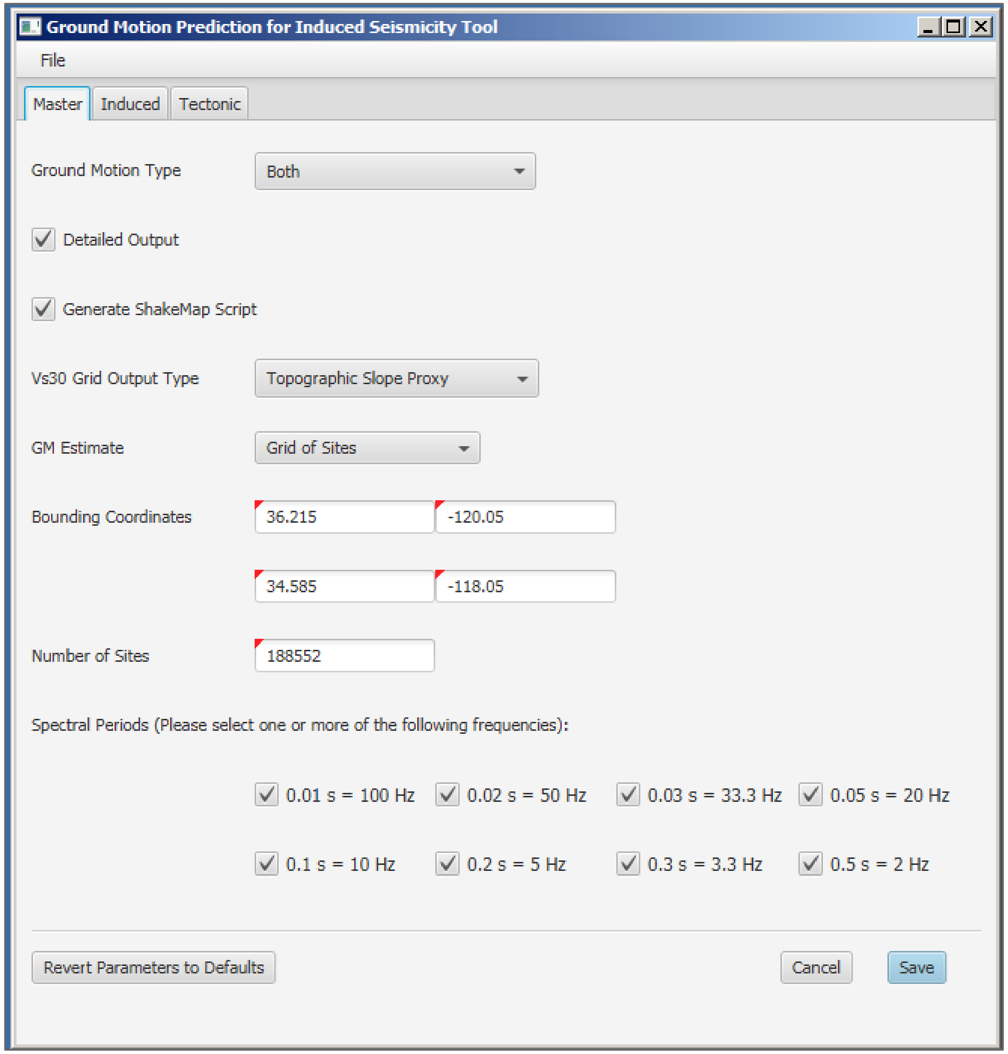
Front Page of GMPIS Tool



Populating the 'Master' File

- The first page opened is the "Master" input page containing desired parameters for both induced and tectonic earthquakes. Note that default parameters are listed all input pages to illustrate working parameters, units and format.
- Ground Motion Type: either "induced", "tectonic", or "both". If 'both are selected, results will be the maximum ground motion for both types of events.
- If "detailed output" is desired, then check this box. Otherwise only a flat-file of output is created suitable for input to other programs.
- If a ShakeMap is desired, a script is produced that can be later processed by Global Mapping Tools (GMT)
- "V_{S30} Grid Output type" allows user to select one of three grid files containing V_{S30} values by longitude and latitude.
- "In southern San Joaquin Valley" of California; check box if site is in that area otherwise upload an alternate personal database.
- Enter Grid of sites for multiple site evaluation.
- Bounding coordinates for the grid of sites (used in GMT script).
- Enter number of sites
- Option to revert to defaults
- Select desired oscillator frequencies
- Save

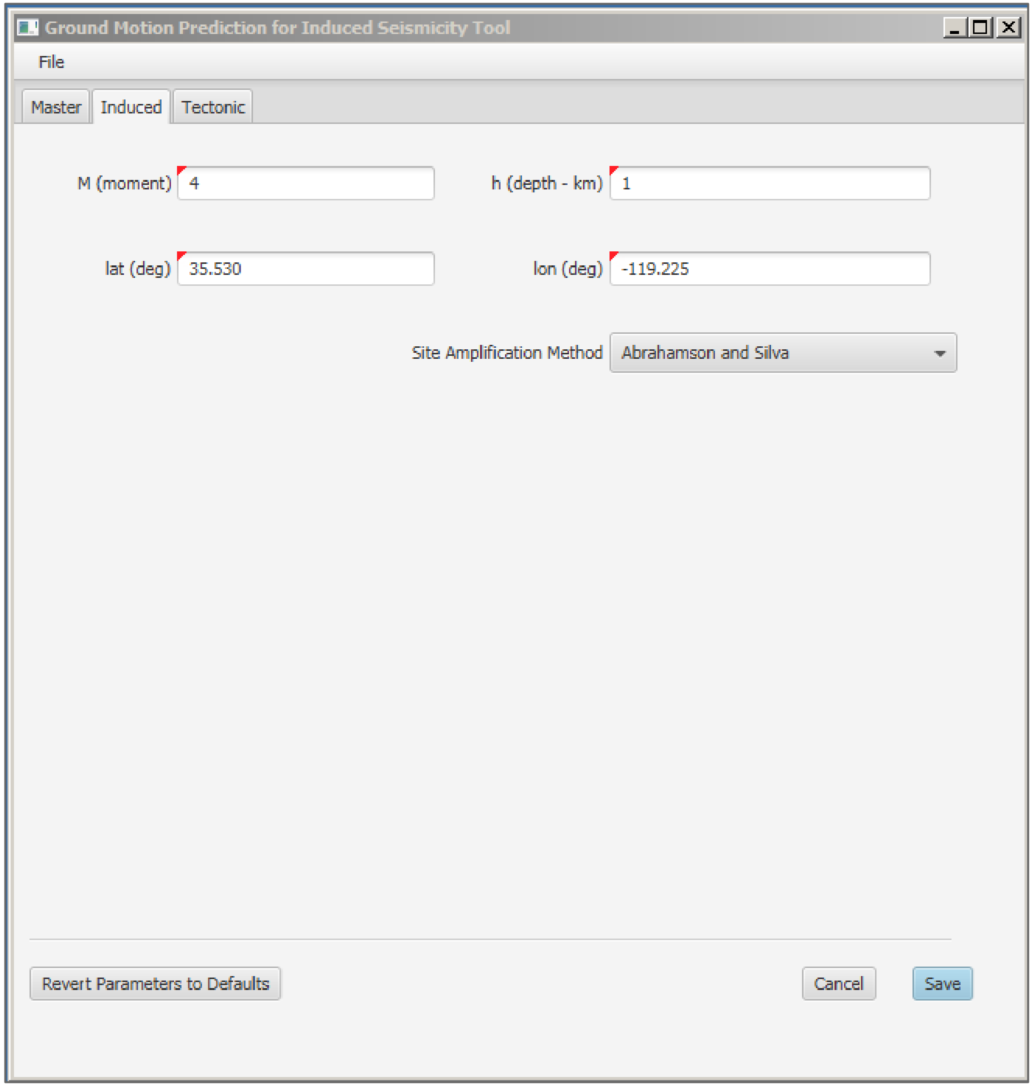
Populating the 'Master' File (continued)



Populating the 'Induced' File

- **Induced input requires simply:**
  - Earthquake moment magnitude
  - Depth
  - Geographic coordinates
  - Site amplification method
  - Save

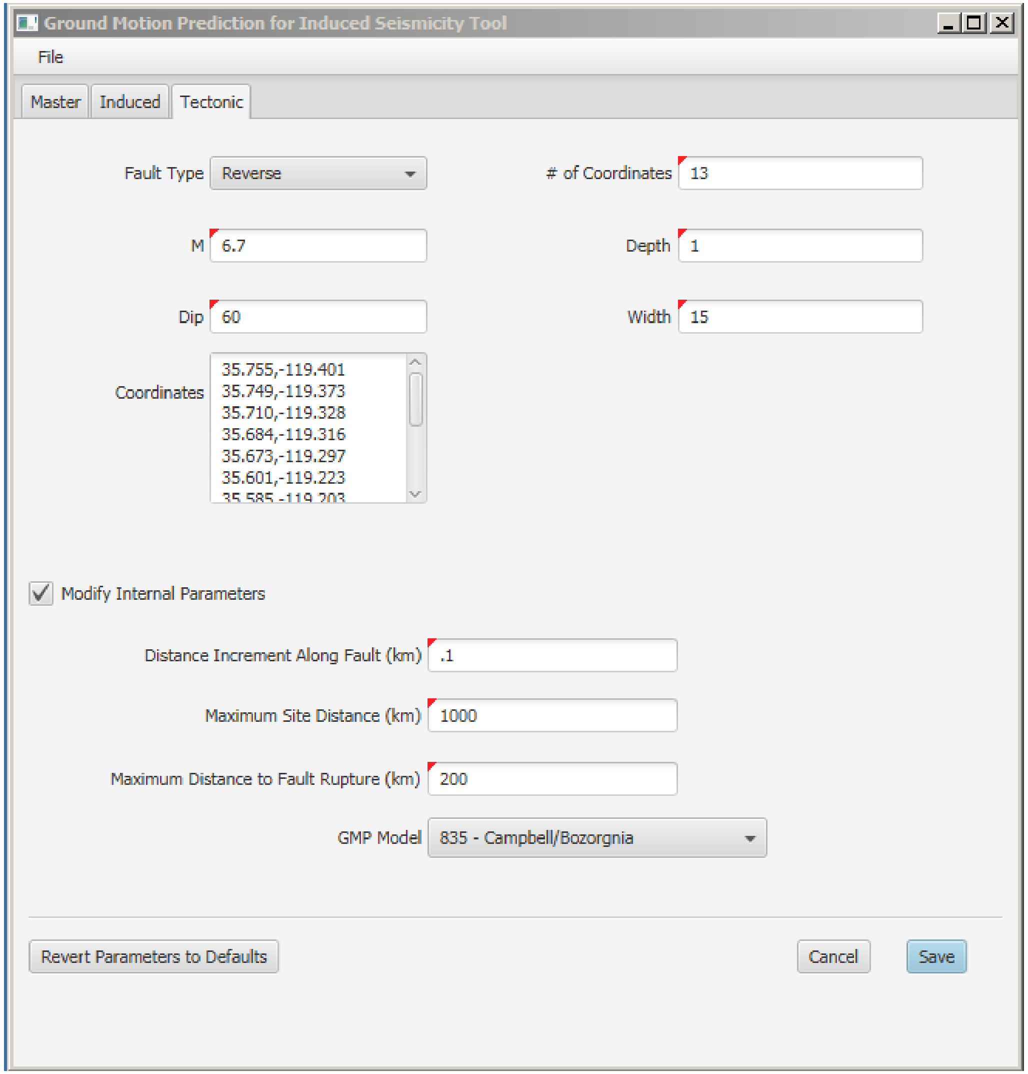
Populating the 'Induced' file (continued)



Populating the 'Tectonic' File

- **If tectonic earthquake input is required, the input parameters are:**
  - Fault type (normal, reverse, strikeslip)
  - Number of geographic coordinates
  - Event magnitude
  - Depth of top of rupture surface (km)
  - Dip of fault (degrees)
  - Width of down-dip rupture surface (km)
  - Latitude and longitude pairs defining top of fault trace
  - If desired, internal parameters can be modified, including (1) distance increment along fault for ground motion evaluation; (2) maximum site distance; (3) maximum distance to fault rupture; (4) NGA-W2 GMP model
  - Save

Populating the 'Tectonic' File (continued)



Generate Output

- Select "Generate" from the Main Page
- Run times depend on number of selected sites and whether induced and/or tectonic events are desired; for the default parameters, run times of several hours are possible (~3 hours to run default parameters on Dell PC)
- System creates flat file of descriptive and graphics package input files
- The user can read these files into a variety of plotters or graphics files for visualization

Example Output (verbose.out)

- Induced Event Response
- Event Coordinates: -108.799 41.7126
- Event Magnitude (Mw): 4.00000
- Event Depth (km): 3.50000
- Area of Interest Coordinates: -109.000 -108.500 41.9000 41.5000
- ***
- Site #: 1
- Site Coordinates: -109.000 41.9000
- Source to Site Distance (km): 26.9174
- Vs30 = 904.203
- Site Amplification: Abrahamson&Silva '13
-
- Period (sec) Median GM (g) sigma (ln)
- 0.100 0.00793 0.98300
- 0.010 0.00176 1.30270
- 0.020 0.00164 1.35280
- 0.030 0.00176 1.43560
- 0.050 0.00316 1.37190
- 0.200 0.00729 0.86010
- 0.300 0.00495 0.85530
- 0.500 0.00199 0.90310
- ***
- Site #: 2
- Site Coordinates: -108.999 41.9000
- Source to Site Distance (km): 26.8663
- Vs30 = 719.740
- Site Amplification: Abrahamson&Silva '13
-
- Period (sec) Median GM (g) sigma (ln)
- 0.100 0.00951 0.98300
- 0.010 0.00199 1.30270
- 0.020 0.00185 1.35280
- 0.030 0.00199 1.43560

Example Output (induced.out)

- **1 -109.000 41.900 4.0 26.92 0.10 0.79311E-02 0.98300E+00 0.01 0.17581E-02 0.13027E+01 0.02 0.16358E-02 0.13528E+01 0.03 0.17584E-02 0.14356E+01 0.05 0.31625E-02 0.13719E+01 0.20 0.72889E-02 0.86010E+00 0.30 0.49473E-02 0.85530E+00 0.50 0.19858E-02 0.90310E+00**
- **2 -108.999 41.900 4.0 26.87 0.10 0.95079E-02 0.98300E+00 0.01 0.19885E-02 0.13027E+01 0.02 0.18510E-02 0.13528E+01 0.03 0.19890E-02 0.14356E+01 0.05 0.35758E-02 0.13719E+01 0.20 0.88726E-02 0.86010E+00 0.30 0.60529E-02 0.85530E+00 0.50 0.24023E-02 0.90310E+00**
- **3 -108.998 41.900 4.0 26.81 0.10 0.10689E-01 0.98300E+00 0.01 0.21506E-02 0.13027E+01 0.02 0.20026E-02 0.13528E+01 0.03 0.21512E-02 0.14356E+01 0.05 0.38669E-02 0.13719E+01 0.20 0.10122E-01 0.86010E+00 0.30 0.69638E-02 0.85530E+00 0.50 0.27619E-02 0.90310E+00**
- **4 -108.997 41.900 4.0 26.76 0.10 0.95339E-02 0.98300E+00 0.01 0.19974E-02 0.13027E+01 0.02 0.18596E-02 0.13528E+01 0.03 0.19987E-02 0.14356E+01 0.05 0.35950E-02 0.13719E+01 0.20 0.88781E-02 0.86010E+00 0.30 0.60538E-02 0.85530E+00 0.50 0.24038E-02 0.90310E+00**
- **5 -108.996 41.900 4.0 26.71 0.10 0.90296E-02 0.98300E+00 0.01 0.19290E-02 0.13027E+01 0.02 0.17957E-02 0.13528E+01 0.03 0.19307E-02 0.14356E+01 0.05 0.34744E-02 0.13719E+01 0.20 0.83491E-02 0.86010E+00 0.30 0.56763E-02 0.85530E+00 0.50 0.22595E-02 0.90310E+00**
- **6 -108.995 41.900 4.0 26.66 0.10 0.93985E-02 0.98300E+00 0.01 0.19839E-02 0.13027E+01 0.02 0.18471E-02 0.13528E+01 0.03 0.19858E-02 0.14356E+01 0.05 0.35739E-02 0.13719E+01 0.20 0.87168E-02 0.86010E+00 0.30 0.59356E-02 0.85530E+00 0.50 0.23593E-02 0.90310E+00**
- **7 -108.994 41.900 4.0 26.61 0.10 0.96049E-02 0.98300E+00 0.01 0.20154E-02 0.13027E+01 0.02 0.18766E-02 0.13528E+01 0.03 0.20177E-02 0.14356E+01 0.05 0.36319E-02 0.13719E+01 0.20 0.89199E-02 0.86010E+00 0.30 0.60794E-02 0.85530E+00 0.50 0.24155E-02 0.90310E+00**
- **8 -108.993 41.900 4.0 26.56 0.10 0.99048E-02 0.98300E+00 0.01 0.20597E-02 0.13027E+01 0.02 0.19181E-02 0.13528E+01 0.03 0.20623E-02 0.14356E+01 0.05 0.37127E-02 0.13719E+01 0.20 0.92219E-02 0.86010E+00 0.30 0.62952E-02 0.85530E+00 0.50 0.25000E-02 0.90310E+00**
- **9 -108.992 41.900 4.0 26.51 0.10 0.11587E-01 0.98300E+00 0.01 0.22857E-02 0.13027E+01 0.02 0.21294E-02 0.13528E+01 0.03 0.22886E-02 0.14356E+01 0.05 0.41190E-02 0.13719E+01 0.20 0.11016E-01 0.86010E+00 0.30 0.76148E-02 0.85530E+00 0.50 0.30247E-02 0.90310E+00**
- **10 -108.991 41.900 4.0 26.46 0.10 0.12550E-01 0.98300E+00 0.01 0.24107E-02 0.13027E+01 0.02 0.22465E-02 0.13528E+01 0.03 0.24141E-02 0.14356E+01 0.05 0.43449E-02 0.13719E+01 0.20 0.12066E-01 0.86010E+00 0.30 0.84020E-02 0.85530E+00 0.50 0.33428E-02 0.90310E+00**
- **11 -108.990 41.900 4.0 26.41 0.10 0.13787E-01 0.98300E+00 0.01 0.25673E-02 0.13027E+01 0.02 0.23932E-02 0.13528E+01 0.03 0.25713E-02 0.14356E+01 0.05 0.46275E-02 0.13719E+01 0.20 0.13414E-01 0.86010E+00 0.30 0.94270E-02 0.85530E+00 0.50 0.37608E-02 0.90310E+00**
- **12 -108.989 41.900 4.0 26.36 0.10 0.18183E-01 0.98300E+00 0.01 0.30738E-02 0.13027E+01 0.02 0.28674E-02 0.13528E+01 0.03 0.30783E-02 0.14356E+01 0.05 0.55367E-02 0.13719E+01 0.20 0.18496E-01 0.86010E+00 0.30 0.13396E-01 0.85530E+00 0.50 0.53919E-02 0.90310E+00**
- **13 -108.988 41.900 4.0 26.31 0.10 0.11588E-01 0.98300E+00 0.01 0.22986E-02 0.13027E+01 0.02 0.21419E-02 0.13528E+01 0.03 0.23032E-02 0.14356E+01 0.05 0.41492E-02 0.13719E+01 0.20 0.10960E-01 0.86010E+00 0.30 0.75624E-02 0.85530E+00 0.50 0.30050E-02 0.90310E+00**
- **14 -108.987 41.900 4.0 26.26 0.10 0.11153E-01 0.98300E+00 0.01 0.22450E-02 0.13027E+01 0.02 0.20919E-02 0.13528E+01 0.03 0.22499E-02 0.14356E+01 0.05 0.40547E-02 0.13719E+01 0.20 0.10474E-01 0.86010E+00 0.30 0.71995E-02 0.85530E+00 0.50 0.28600E-02 0.90310E+00**

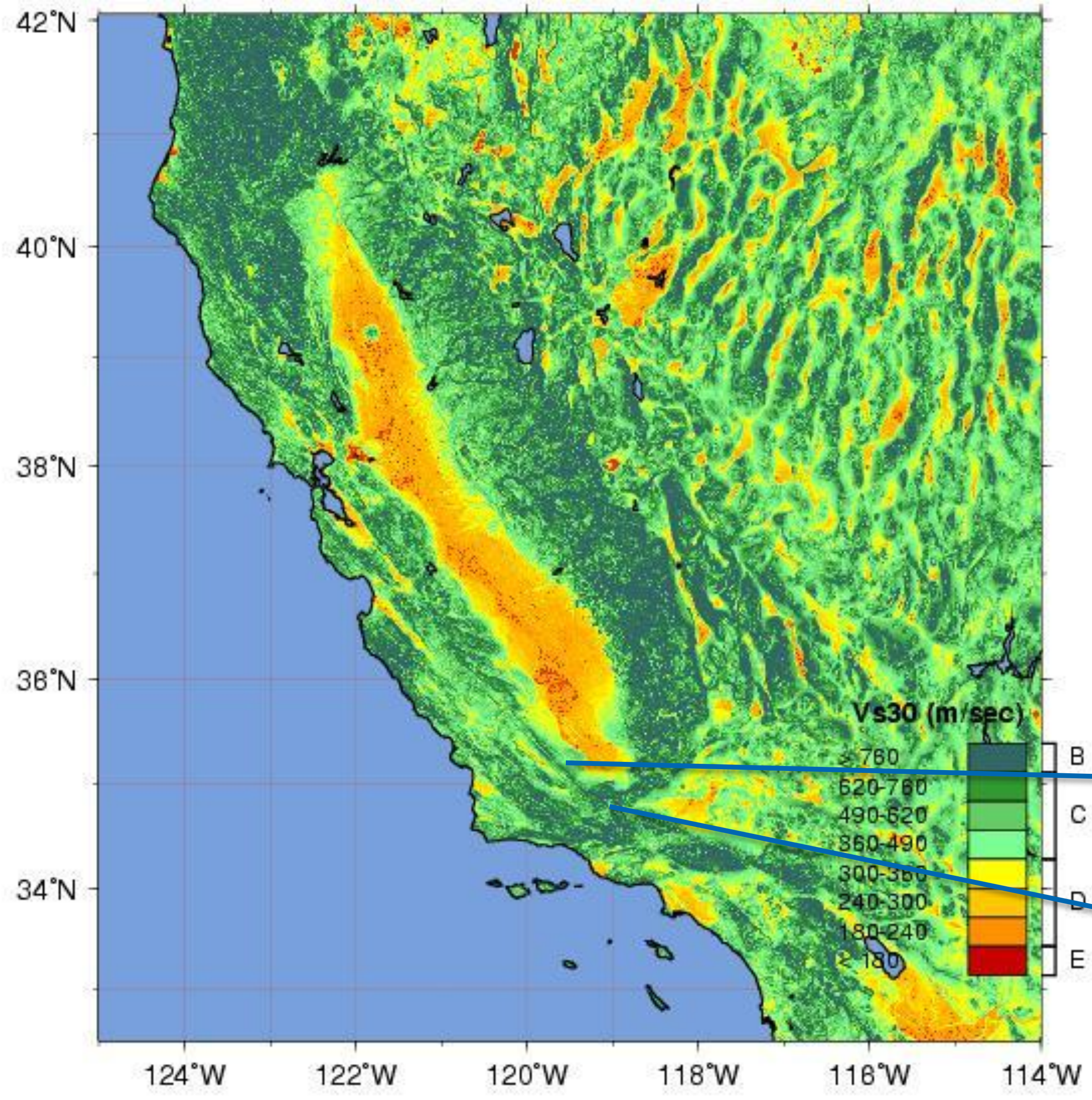
Example GMP v5.2 script for plotting a 'ShakeMap'

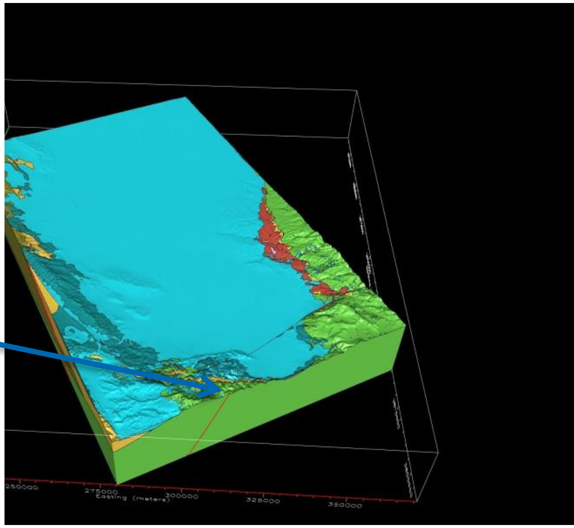
```
surface Acc.xyz -GAcc.grd -R-109/-108.5/41.5/42 -I.001 -T.25
/bin/rm map.ps
grdimage dem.march2016.grd -X4 -Y18 -R-109./-108.5/41.5/42      -JM6 -Cwyoming.cpt -P -K > map.ps
grdcontour Acc.grd -R -JM -C.05  -A.01+f10p -Gd3  -Wthin,0 -O -K >> map.ps
grdcontour Acc.grd -R -JM -C.1  -A.01+f10p -Wthinnest,0 -O -K >> map.ps
pscoast -R -JM  -Dl  -A4000 -B.25g.25  -Wthinnest,0    -P  -O -K >> map.ps
psxy box.xyz -JM -R -W1,white -O -K -P -: >> map.ps
psxy point.xy -JM     -R  -Sc.20 -Gwhite -Wthinnest -L  -P  -K -O >> map.ps
pstext  -X.1 -JM -R -F+f10p,Helvetica,white+jBL       -P    -O -K <<END>> map.ps
-108.8   41.71   Epicenter of hypotheical
-108.8   41.69   hypothetical M4
-108.8   41.67   induced earthquake
END
psscale  -X-.1 -Cwyoming.cpt -D3/-1/7/.25h -B100:"Elevation(m)":  -O  -K >> map.ps
#
#
#
#
grdimage -Y-12 Acc.grd  -R -JM -CAcc.cpt -P -K -O >> map.ps
grdcontour dem.march2016.grd -R -JM -C200 -Wthin,0 -O -K >> map.ps
grdcontour dem.march2016.grd -R -JM -C100  -Wthinnest,0 -O -K >> map.ps
psxy box.xyz -JM -R -W1,yellow -O -K -P -: >> map.ps
psxy point.xy -JM     -R  -Sc.20 -Gwhite -Wthinnest -L  -P  -K -O >> map.ps
pscoast -R -JM  -Dl  -A4000 -B.2g.2  -Wthinnest,0    -P  -O -K >> map.ps
psscale  -CAcc.cpt -D3/-1/7/.25h -B.05:"10-Hz Median Spectral Acceleration (g)":  -O  >> map.ps
#
```

GMPIS Applications: Engineering Seismology Perspective

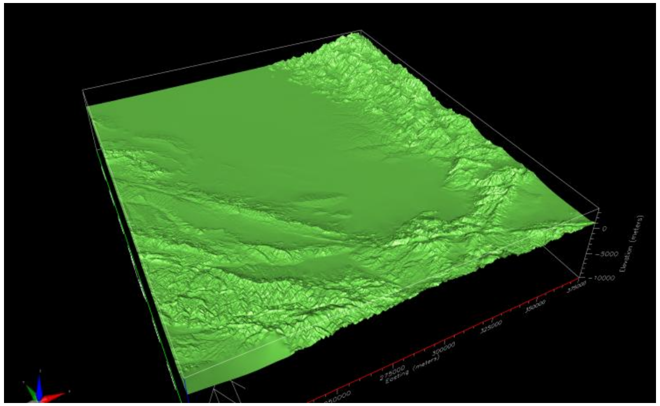
- Practical application of GMPIS NRAP to "green-field" site
  - Consequences (potential bias in GMPE median; excessively large sigma; excessively large predicted probabilistic and deterministic ground motions)
- **Prior to injection (green-field site): use of existing technologies to reduce variability and uncertainty:**
  - Active surface and subsurface geophysical interpretation/characterization: site effects
  - Passive surface and subsurface seismic monitoring: source, path, site
  - Baseline background seismicity rates; source description
- **During injection phase: further reduction of variability and uncertainty in GMP:**
  - Use IS instrumental data further to calibrate source, path and site model
  - Likely unique interpretation for each injection region
- **Integration of IS and tectonic GMPEs in risk assessment model**
  - unique to every region

California Survey V_{S30} : Kimberlina V_{S30} based on slope

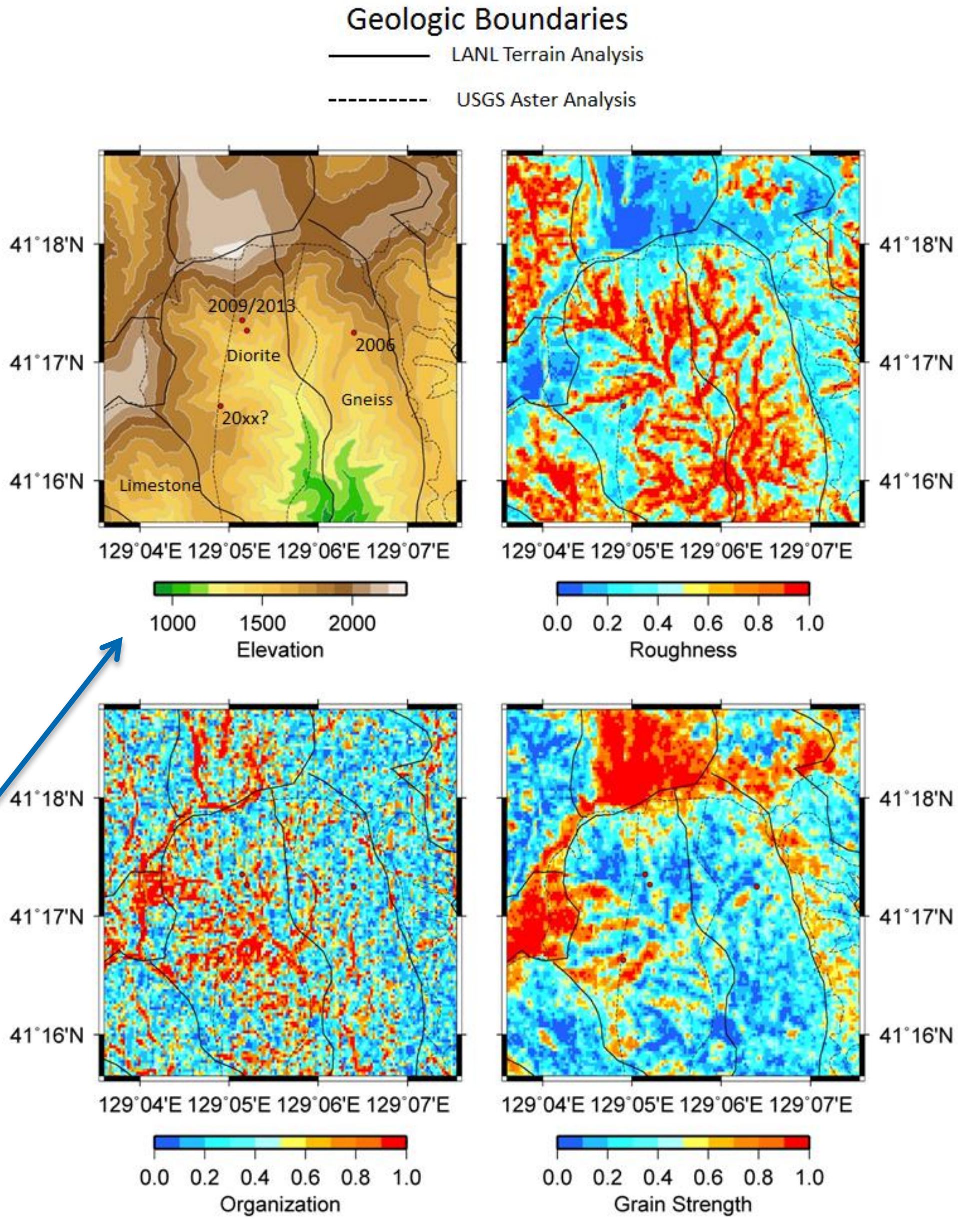


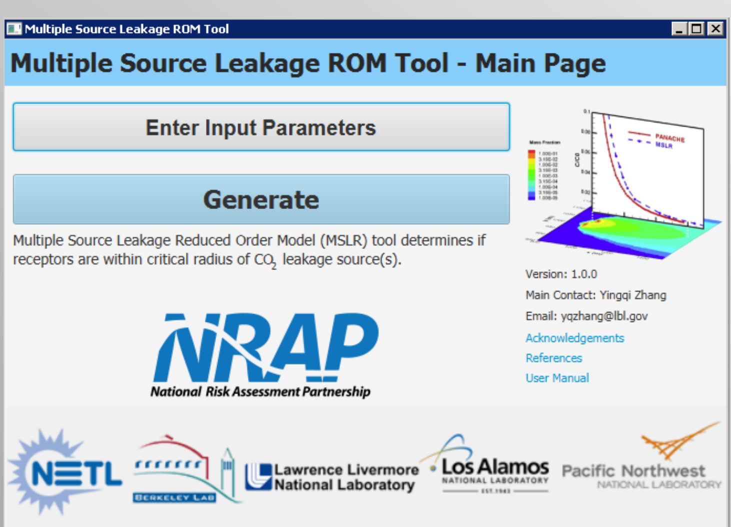


Kimberlina Topographic analysis



Example of geomophometric analysis of the terrain in North Korea





NRAP Tool Webinar Series

Webinar

NRAP - Multiple Source Leakage ROM (MSLR) Tool

June 20, 2016

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Curtis M. Oldenburg[1]

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NRAP
National Risk Assessment Partnership

U.S. DEPARTMENT OF ENERGY | National Energy Technology Laboratory

Outline

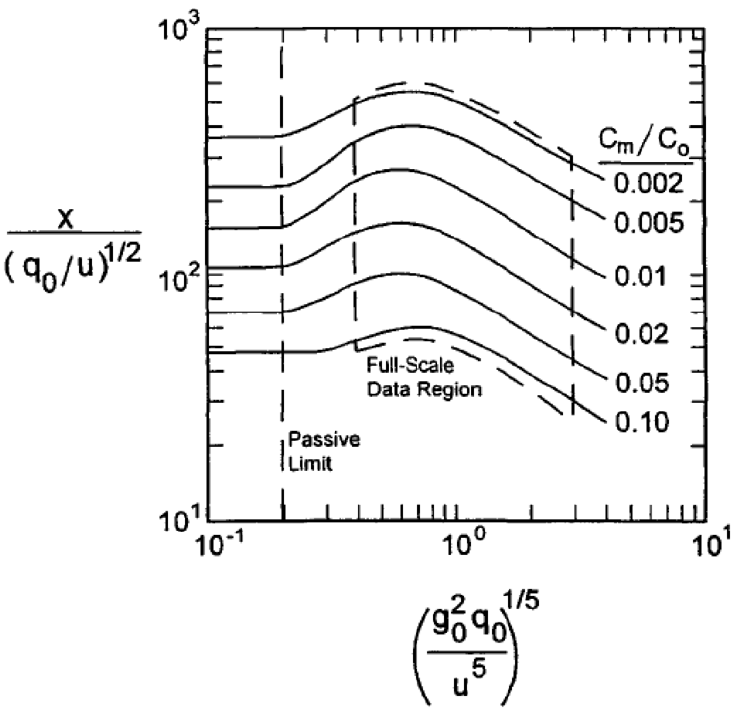
- **Multiple Source Leakage ROM (MSLR)**
  - Goal
  - Approach
  - Input specification
  - Output specification
- **Example**
  - Example setup
  - Results and discussion

MSLR in the Context of NRAP

- **Key definition in the MSLR**
  - Receptors: home or business locations where people are present
  - Critical concentration: a threshold concentration limit above which CO_2 becomes hazardous
  - Critical radii: the radius of CO_2 concentration that is above the critical concentration
- **Goal of MSLR**
  - To evaluate the probability that the receptors are located within critical radii **FAST**

Single Point Release

- **Continuous (vs. instantaneous) release:** $$\frac{uR_d}{x} \geq 2.5$$
- **Dense gas release:** $$\left(\frac{g_0 q_0}{D_c u^3}\right)^{1/3} \geq 0.15$$
- **Critical radius**



R_d: release duration (s)
x : downwind distance (m)
u : wind speed (m/s) at 10 m height

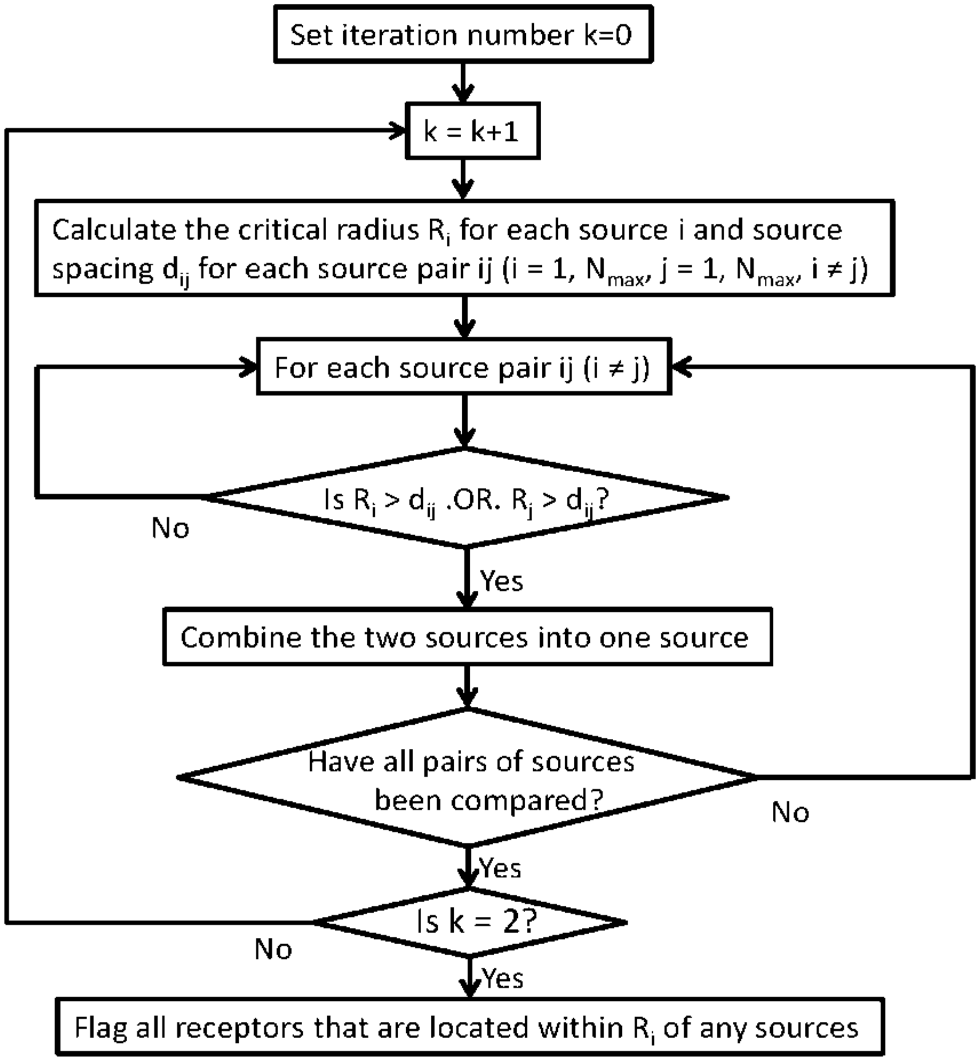
$$g_0 = \frac{g(\rho_0 - \rho_a)}{\rho_a}$$

$$D_c = \left(\frac{q_0}{u}\right)^{0.5}$$

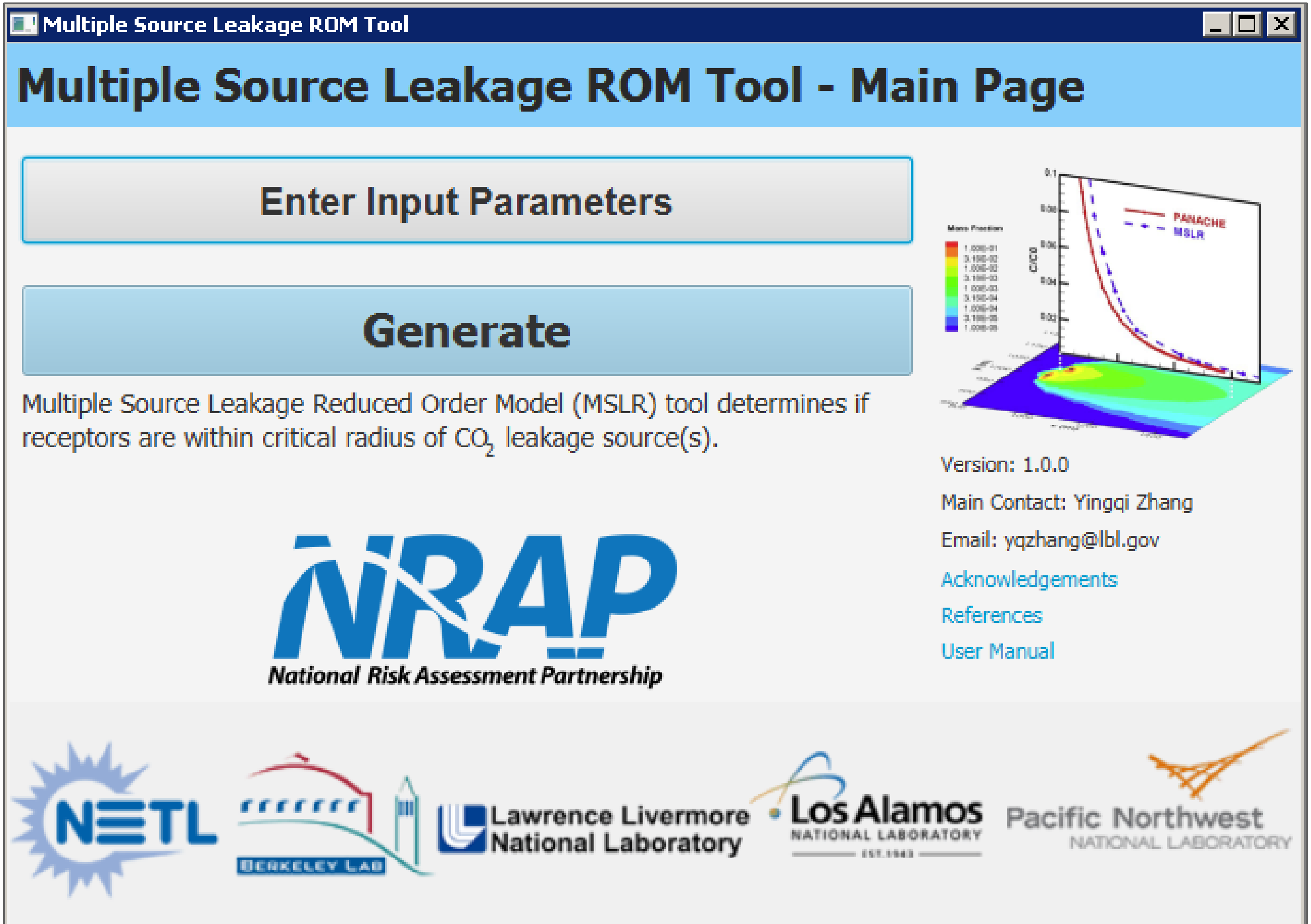
q_0: initial plume volume flux (m^3/s)
g : gravity factor (m/s^2)
ρ_0: initial density of released gas (kg/m^3)
ρ_a: density of ambient air (kg/m^3)

Britter, R.E., and J. D. McQuaid. "Workbook on the dispersion of dense gases." Contract Research Report 17 Health and Safety Executive, Sheffield, UK (1988)

MSLR Approach

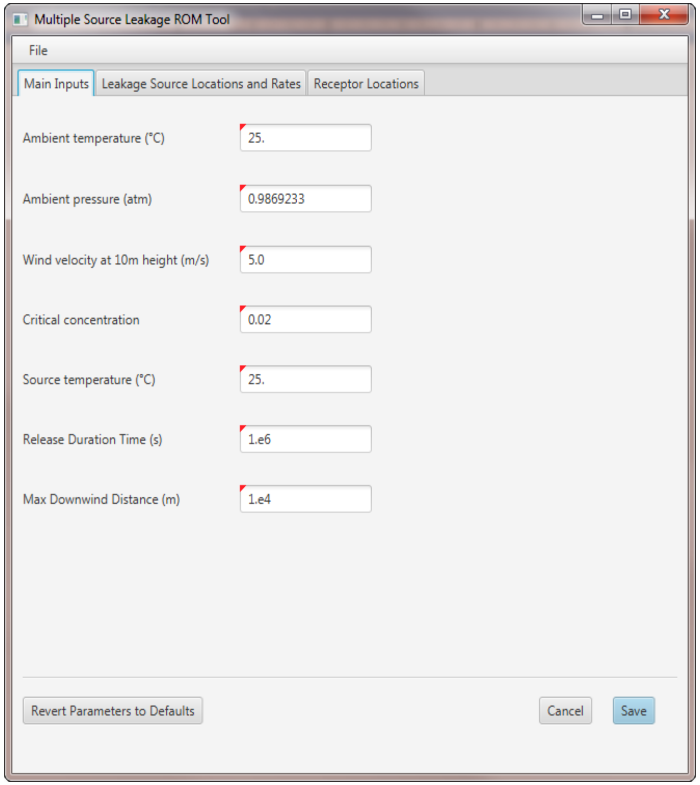


Main Window


Multiple Source Leakage ROM Tool
Multiple Source Leakage ROM Tool - Main Page
Enter Input Parameters
Generate
Multiple Source Leakage Reduced Order Model (MSLR) tool determines if receptors are within critical radius of CO_2 leakage source(s).
PANACHE
MSLR
Version: 1.0.0
Main Contact: Yingqi Zhang
Email: yqzhang@lbl.gov
Acknowledgements
References
User Manual
NRAP
National Risk Assessment Partnership
NETL
Berkeley Lab
Lawrence Livermore National Laboratory
Los Alamos National Laboratory
Pacific Northwest National Laboratory

Three Types of Input

- **Main input:**
  - Ambient pressure
  - Ambient temperature
  - Wind velocity at 10 m height
  - Critical concentration
  - Source temperature
  - Release time (stand-alone only)
  - maximum downwind distance (stand-alone only)
- **Leakage source location and rates**
- **Receptor locations**



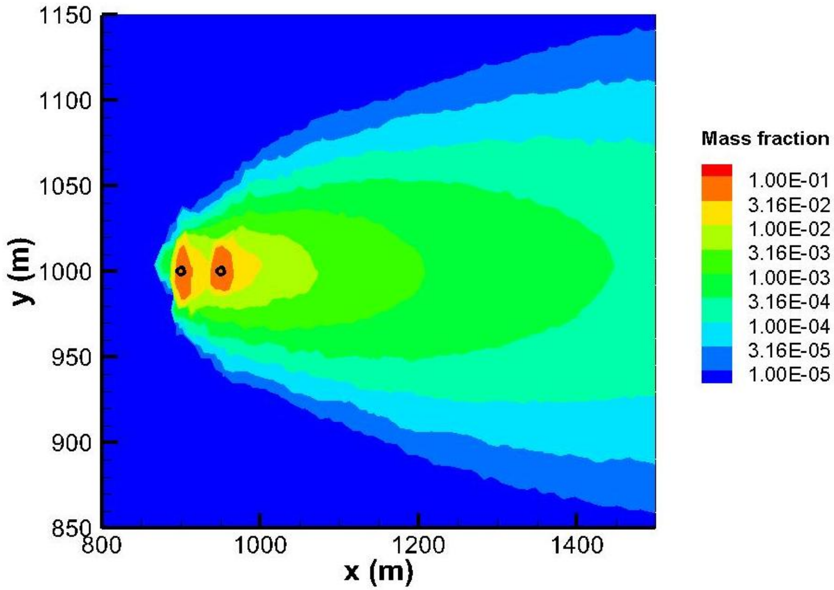
Two Types of Output

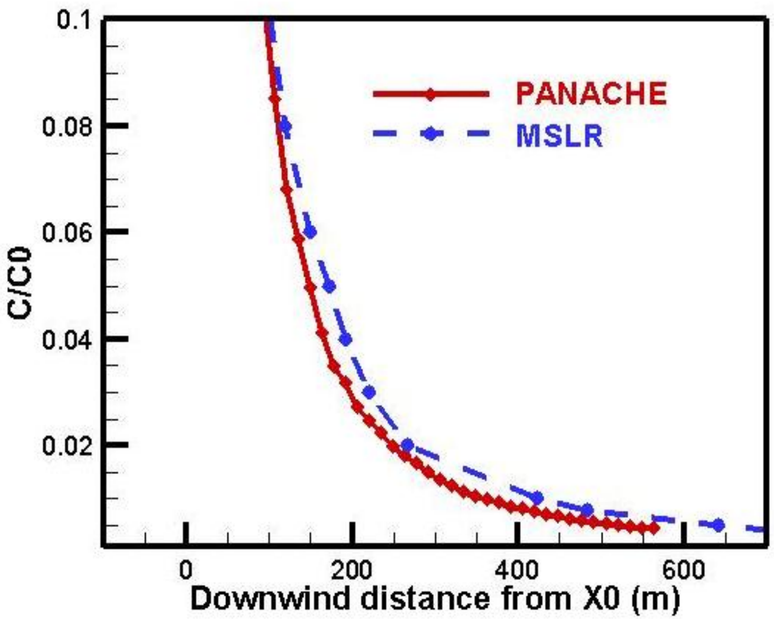
- **Results related to CO_2 concentration at receptors (in File "Receptor.dat"):**
  - Receptor_Flag: to identify if CO_2 concentration at each receptor is above critical concentration
  - TotalNum_above_critical: the total number of receptors that have a CO_2 concentration above critical concentration
- **Results related to critical zone (in File "CriticalDistance.dat"):**
  - The new CO_2 leakage locations and leakage rates (Location_of_PotentialLeak, Leakage_Rate) after combination of the leakage sources
  - The critical radius (critical_radius) of each leakage source to define critical zone

An Example

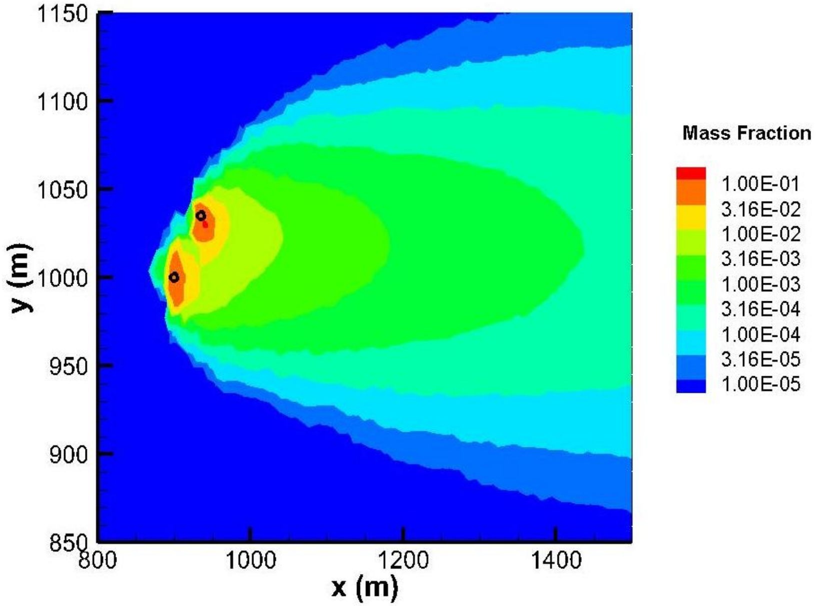
- **Two sources are 50 m apart**
- **Main inputs**
  - Ambient pressure: 0.987 atm
  - Ambient temperature: 25 °C
  - Wind velocity at 10 m height: 5 m/s
  - Critical concentration: various
  - Source temperature: 25°C

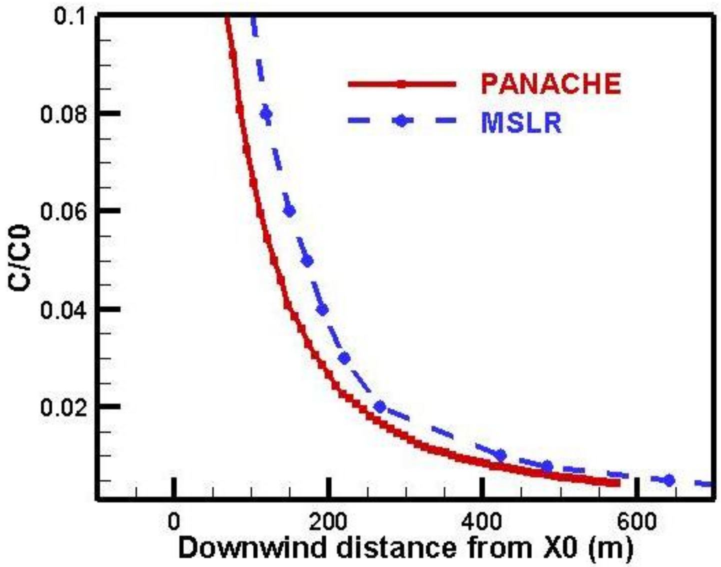
Case 1: Wind Direction Aligned With The Two Sources





Case 2: Wind Direction Not Aligned With The Two Sources





Questions?

MSLR tool

Questions/comments not addressed during the scheduled meeting time can be addressed to NRAP@netl.doe.gov

Acknowledgements

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Thank you!

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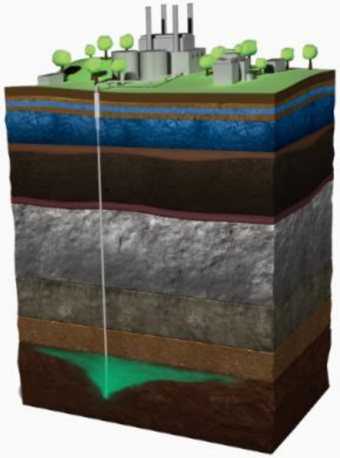
Become an NRAP Tool Beta Tester!

NRAP leverages DOE's capabilities to help quantify uncertainties and risks necessary to remove barriers to full-scale CO_2 storage deployment.

NETL's Office of Research and Development (ORD) is leading a multi-laboratory effort that leverages broad technical capabilities across the DOE complex into a mission-focused platform that will develop the integrated science base that can be applied to risk assessment for long-term storage of CO_2: the National Risk Assessment Partnership (NRAP). NRAP involves five DOE national laboratories: NETL, Los Alamos National Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, and Pacific Northwest National Laboratory.



The motivating goal of NRAP is to develop science-based methodologies and tools for calculating risks at any CO_2 storage site while providing necessary scientific and technological advances to support that methodology. Fiscal Year 2016 will span a period of transition for the NRAP research program, with Phase I of this multi-year research effort expected to come to completion by June 2016, and Phase II research beginning concurrently. Phase I is focused on assessment of risk associated with large-scale CO_2 storage, and with quantifying uncertainties associated with those assessments; Phase II will focus on management of risk associated with large-scale CO_2 storage, and with reducing associated uncertainties.

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