Utah Ground-Shaking Working Group

INTRODUCTION

Annual Meeting #7

11 February 2009

2004 GSWG Plan

- Develop a community velocity model (CVM)
  - V_S30, R1, R2
- Evaluate seismic source and propagation path characteristics of Utah earthquakes, and site amplification and geotechnical characteristics of Utah soils
  - Stress drops, slip distributions, rupture processes
  - Hanging wall effects and directivity
  - Q and kappa
  - Non-linear dynamic soil properties

2004 GSWG Plan (cont.)

- Perform 3D modeling using CVM to evaluate the importance of basin structure on strong ground motions
  - Depth to R2, basin-edge/steep boundary effects
- Prepare large-scale Wasatch Front ground-shaking maps
  - Incorporate site conditions and basin effects

Results of 2008 Meeting: Priorities for 2009 Research

- Coordinate 2009 Working Group meetings with EERI Annual Meeting in SLC in February
- Update CVM with revised site-conditions units and USGS shallow to intermediate-depth data when it becomes available
- Expand CVM to include basins to west (Tooele and Rush Valleys)
- Form working sub-groups to use the validated CVM to develop near-surface site-amplification and basin models
- Transfer CVM to UGS, USGS, and users.

Goals of the 2009 Meeting

- Present results of 2008 research
- Discuss progress on CVM refinement
- Give updates on on-going projects summarized in previous meetings

Goals of the 2009 Meeting (cont.)

- Finalize plans to prepare Wasatch Front urban seismic hazard maps
  - Characterize earthquake sources
  - Develop site-amplification and basin models
  - Prepare maps
- Identify 2010 research priorities

2009 Schedule for Preparing Maps

- Validate the CVM (Magistrale, Olsen, Pechmann)
- Propose site-amplification modeling for 2010 NEHRP (Wong, others)
- Perform basin modeling
- Begin urban hazard map development

Agenda

12:00	**Lunch (provided)**
1:00	Introduction, overview of meeting, USGS-UGS cooperative agreement, review of last year's priorities

<u>Technical presentations</u>

1:20 – 1:35	Ivan Wong, URS; update on NEHRP grant "Inversion for source, path, and site parameters from the Wasatch Front ANSS data."
1:35 – 1:45	Harold Magistrale, SDSU; Update on modifications to CVM and proposal to expand/update CVM and evaluate V_P/V_S ratios and R2 to R3 gradient.
1:45 - 2:15	Kris Pankow, UUSS and Mark Petersen, USGS; Results from 2008 **M** 6.0 Wells, NV earthquake; ground motions/site-amplification in SLV; near-source data – applicability to other (WF) basins.
2:15 – 3:15	Kim Olsen and Daniel Roton, SDSU; Presentation and discussion of Wasatch Front community velocity model (CVM) validation; preliminary 1 Hz 3-dimensional **M** 7.0 scenario ground motion maps.
3:15	**Break**
3:30	Mark Petersen, USGS; USGS perspective of Wasatch Front urban hazard maps – Group discussion; Dynamic modeling – results, comparison of models, direction of modeling, priorities for future research
5:00	**Adjourn**

USGS NEHRP Grant
"Analyses of Earthquake Source, Path, and Site Parameters From ANSS Data Along the Wasatch Front, Utah"

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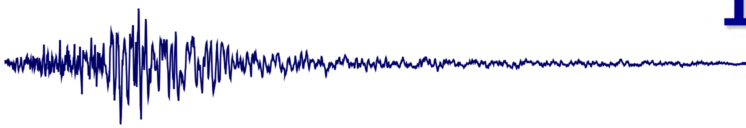


Introduction

- Objective: To evaluate the critical factors that control ground shaking hazard along the Wasatch Front: stress drop, kappa, crustal attenuation, and site amplification.

- Some previous studies have suggested that ground motions in an extensional regime such as the Basin and Range Province may be lower than in California for the same magnitude and distance.

- The inference was that this difference may be due to the lower stress drops of extensional earthquakes compared to compressional earthquakes as first suggested by McGarr (1984).

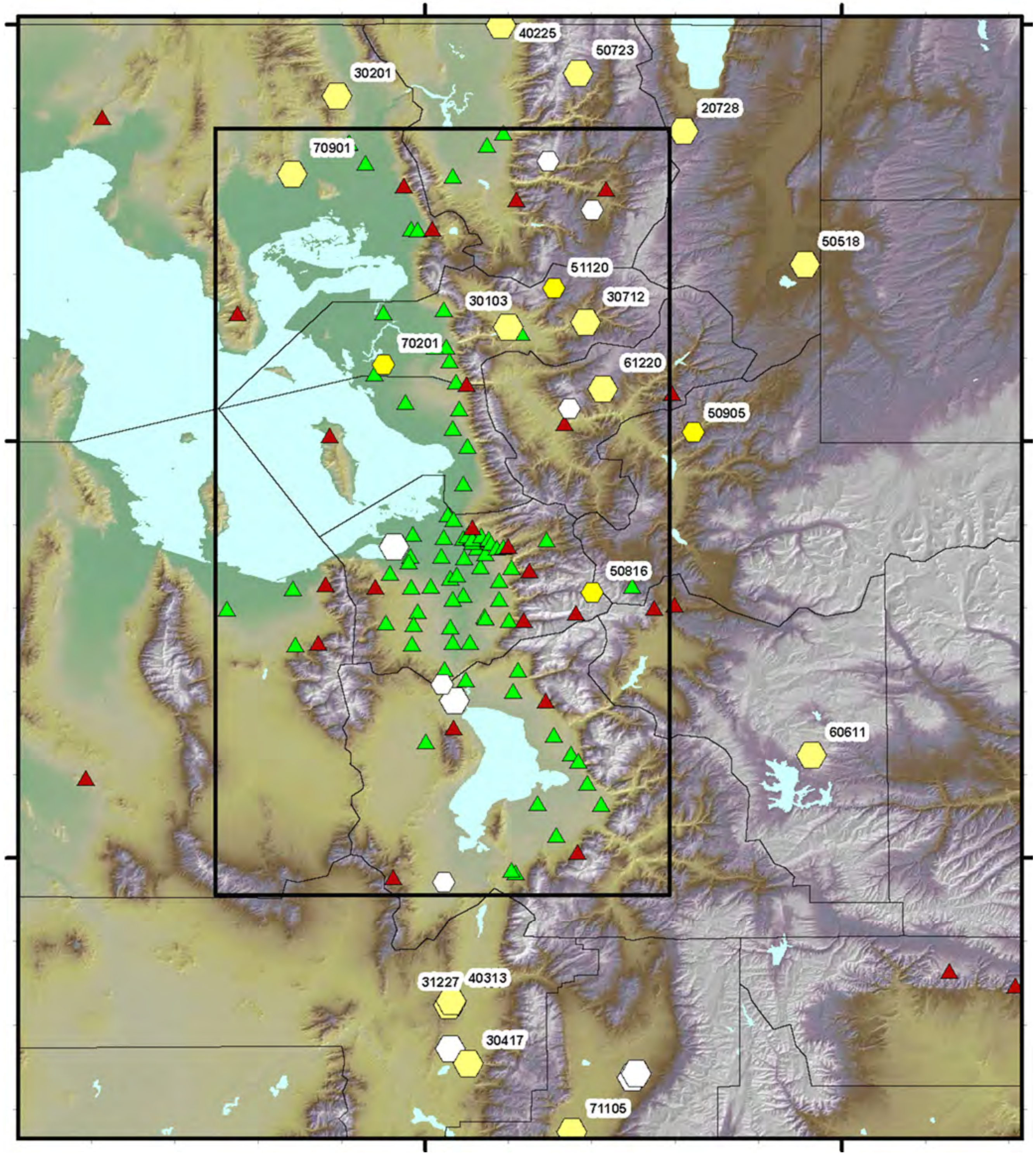
Background

- No systematic evaluation of earthquake stress drops has been performed for earthquakes along the Wasatch Front.
- No studies have been performed to evaluate the variability in kappa in the central Wasatch Front. Kappa can have a very significant effect on high-frequency ground motions with lower values of kappa resulting in larger high-frequency ground motions.
- Only a few studies to estimate Q(f) for the Wasatch Front (Brockman and Bollinger, 1992; Jeon and Herrmann, 2004) have been performed.

Scope of Work

- To analyze the available strong motion and broadband data from ANSS stations in the central Wasatch Front region for stress drop, kappa, and Q(f).
- The approach uses an inversion scheme developed by Walt Silva. In the inversion scheme, earthquake source, path and site parameters are obtained by using a nonlinear least-squares inversion of Fourier amplitude spectra.

Earthquakes Being Evaluated



Earthquakes to be Analyzed

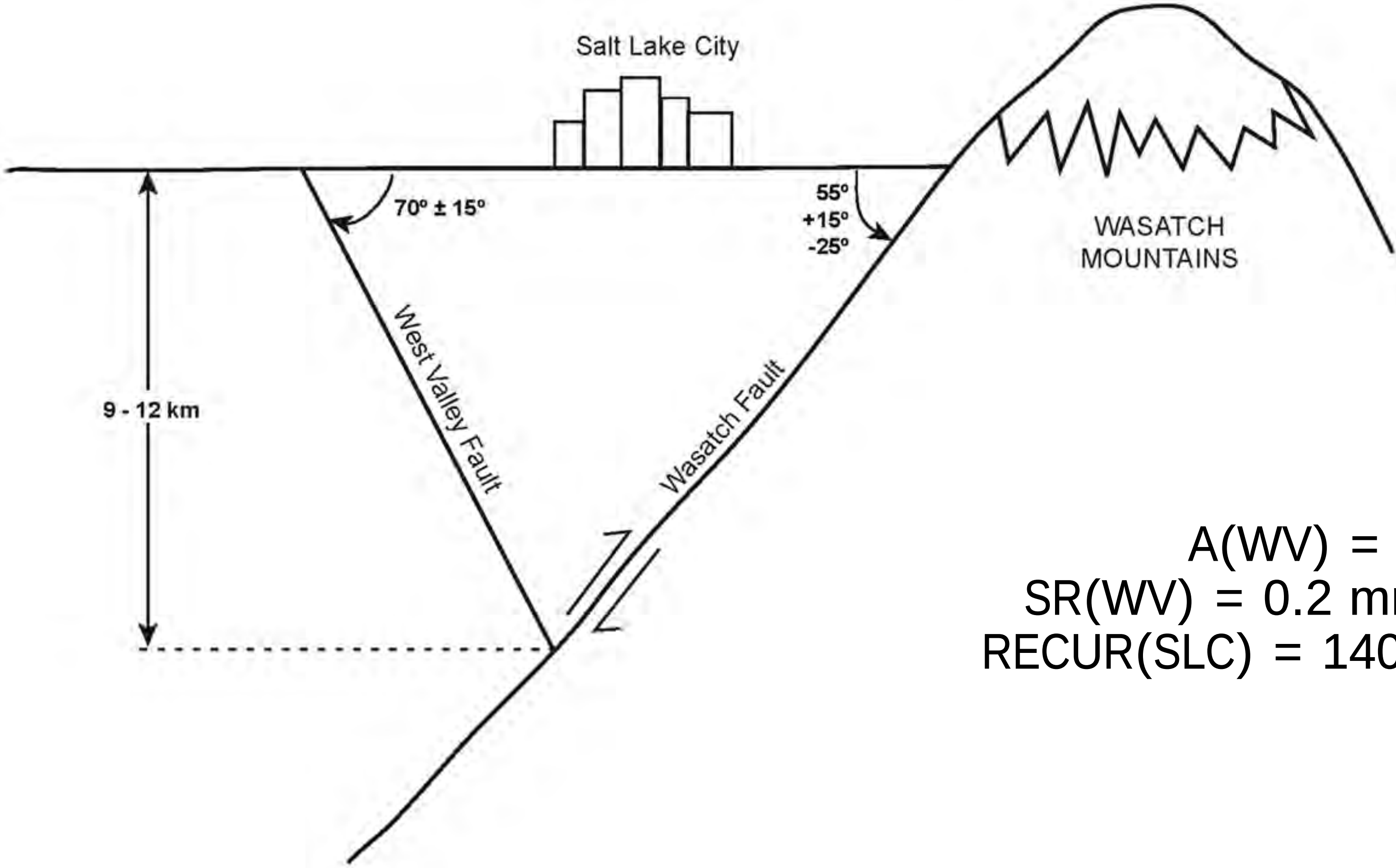
- Total of 15 events
- Period: May 2001 to February 2008
- Magnitude Range: **M** 3.0 to 4.2
- Number of stations recording events: 18 to 68

Scope of Work

- Steps involved in analyses are:

  1) windowing and calculation of Fourier amplitude spectra of each of the recordings;
  2) inversion of the recordings for each earthquake for stress drop, kappa plus a frequency-independent amplification factor for rock sites, and Q(f); and
  3) evaluation of the results.

Coseismic rupture of the West Valley fault and Salt Lake City (SLC) segment occurs when the SLC characteristic earthquake (**M** 7.0 ± 0.3) occurs



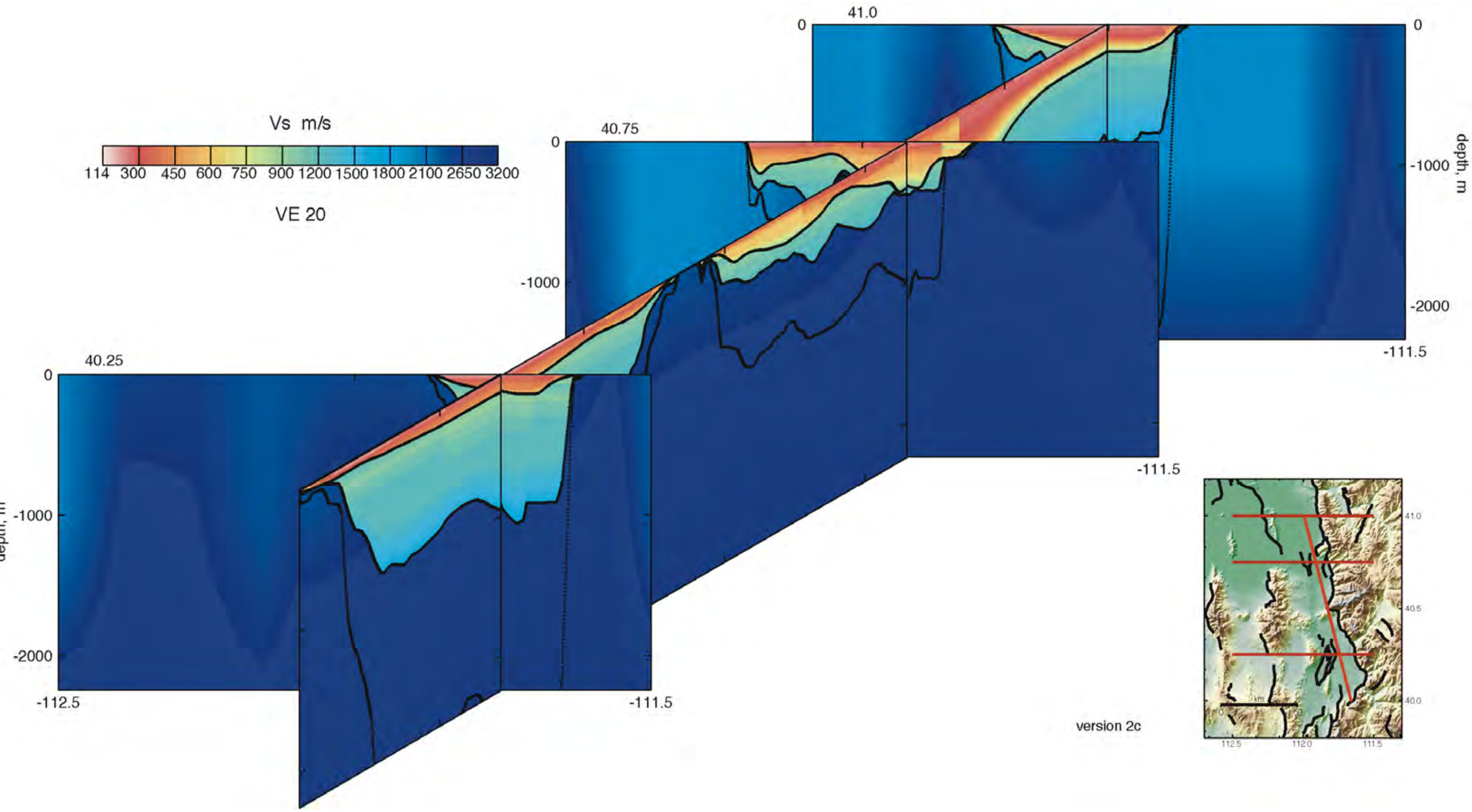
A(WV) = 183 km2
SR(WV) = 0.2 mm/yr (0.03, 0.7)
RECUR(SLC) = 1400 yrs (610, 4090)

M_O = μ*A(WV)*SR(WV)*RECUR(SLC)

M (WV) = (logM_O – 16.05)/1.5

M 5.0 to 6.5

GM = SRSS [GM(WV),GM(SLC)]



Vs m/s
114 300 450 600 750 900 1200 1500 1800 2100 2650 3200
VE 20
41.0
40.75
40.25
0
-1000
-2000
depth, m
-112.5
-111.5
version 2c

Proposed work

Expand the CVM area.

- Add Tooele and Rush basins, Great Salt Lake Basin west of Antelope Island and Promontory Point, and "back valley" basins in the Wasatch Range.

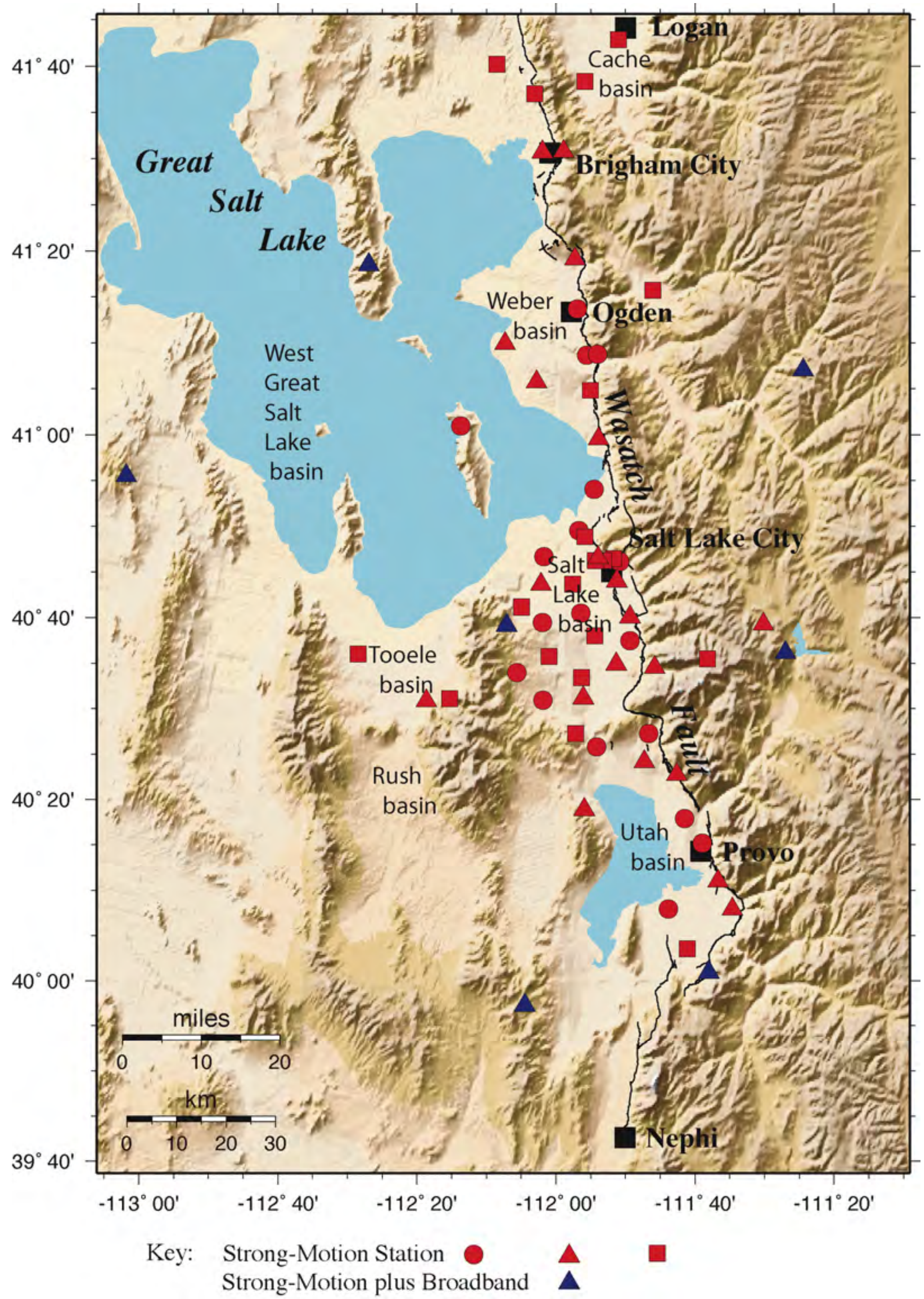
Update CVM with intermediate-depth data.

- P-wave reflection study in the Spanish Fork area in the southern Utah basin.
- SPAC Vs profiles at 14 sites in Salt Lake basin and 4 sites in Utah basin (Stephenson and Williams).

Evaluate Vp/Vs ratios.

Evaluate the R2 to R3 gradient.

- Utah DOGM sonic logs (28 slowness logs to 17,000 ft).


Logan
Cache basin
Great Salt Lake
Brigham City
Weber basin
Ogden
West Great Salt Lake basin
Wasatch Fault
Salt Lake City
Salt Lake basin
Tooele basin
Rush basin
Utah basin
Provo
Nephi
miles
0 10 20
km
0 10 20 30
41° 40'
41° 20'
41° 00'
40° 40'
40° 20'
40° 00'
39° 40'
-113° 00'
-112° 40'
-112° 20'
-112° 00'
-111° 40'
-111° 20'
Key: Strong-Motion Station
Strong-Motion plus Broadband

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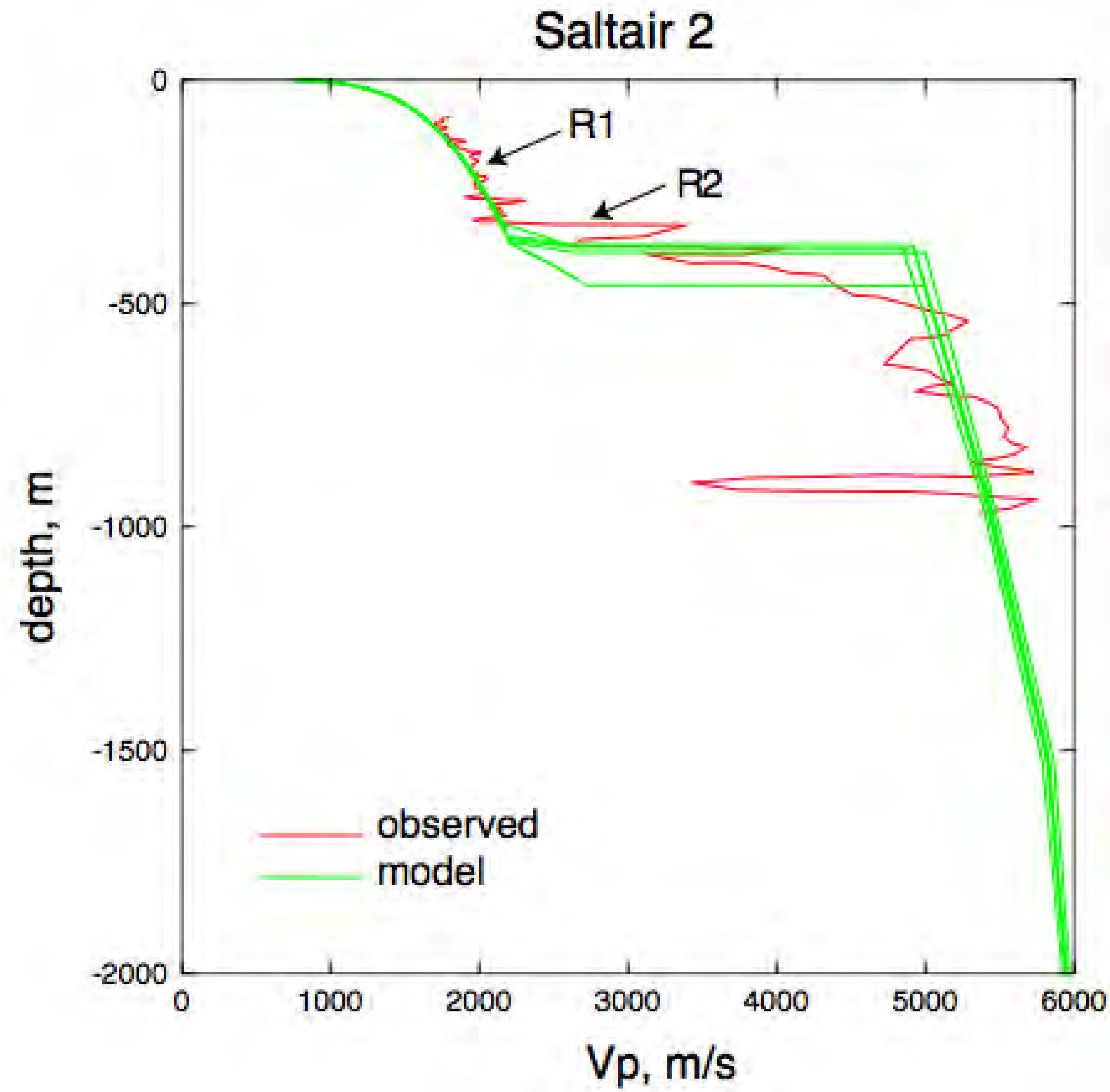

from Radkins et al. 1989

Proposed work

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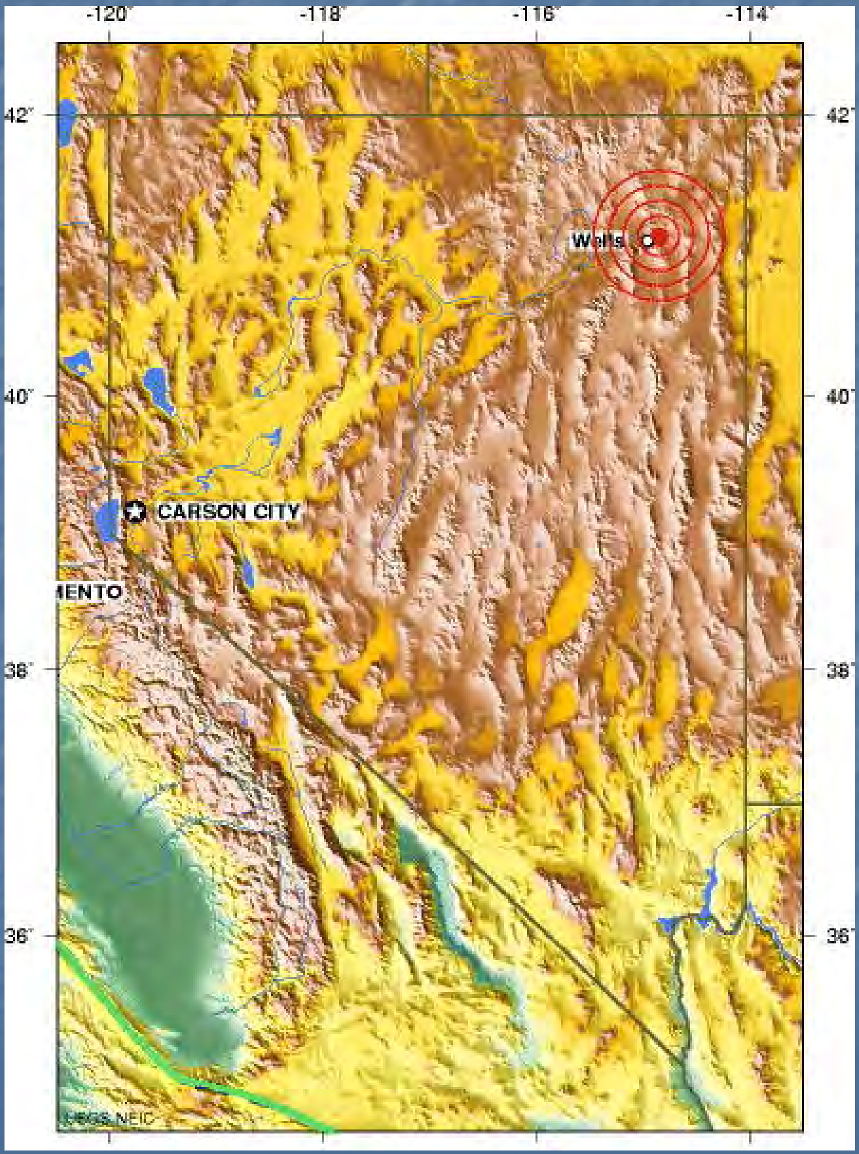
February 21, 2008 Wells Earthquake



Time: 6:16:02 am PST

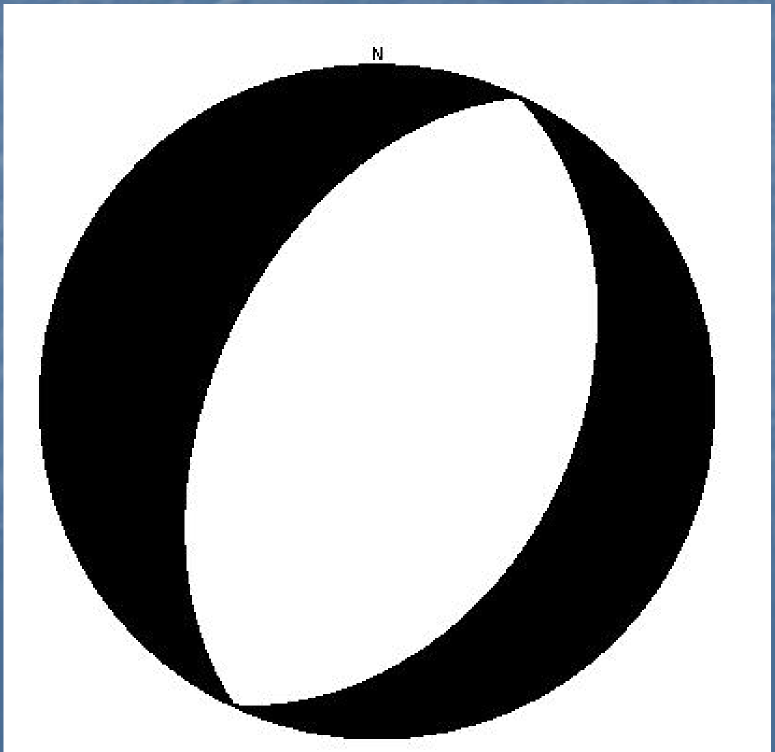
Location: 41.153°N 114.867°W 6.7 km

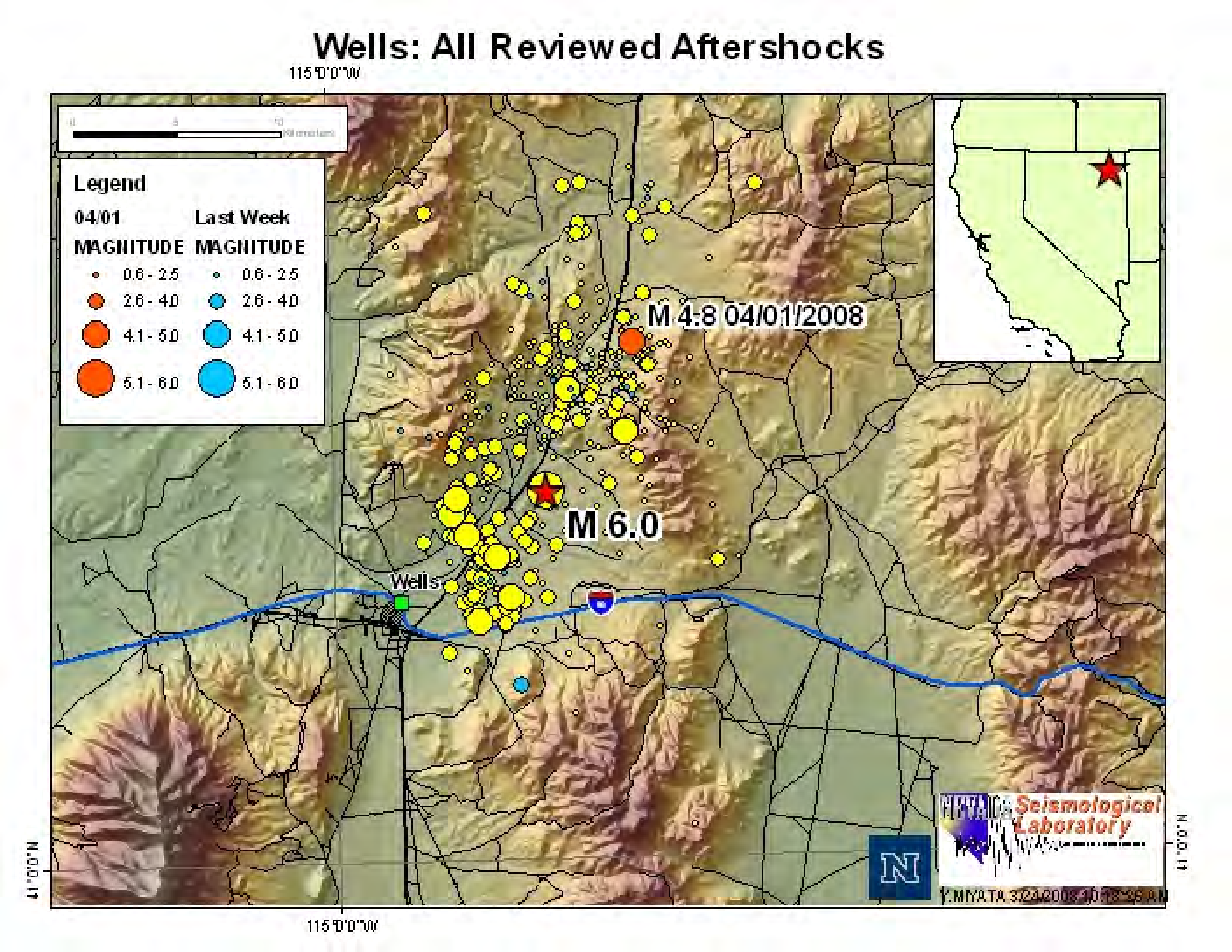
10 km ENE of Wells, Nevada

245 km W of Salt Lake City, UT

Magnitude: Mw 6.0

Focal Mechanism:

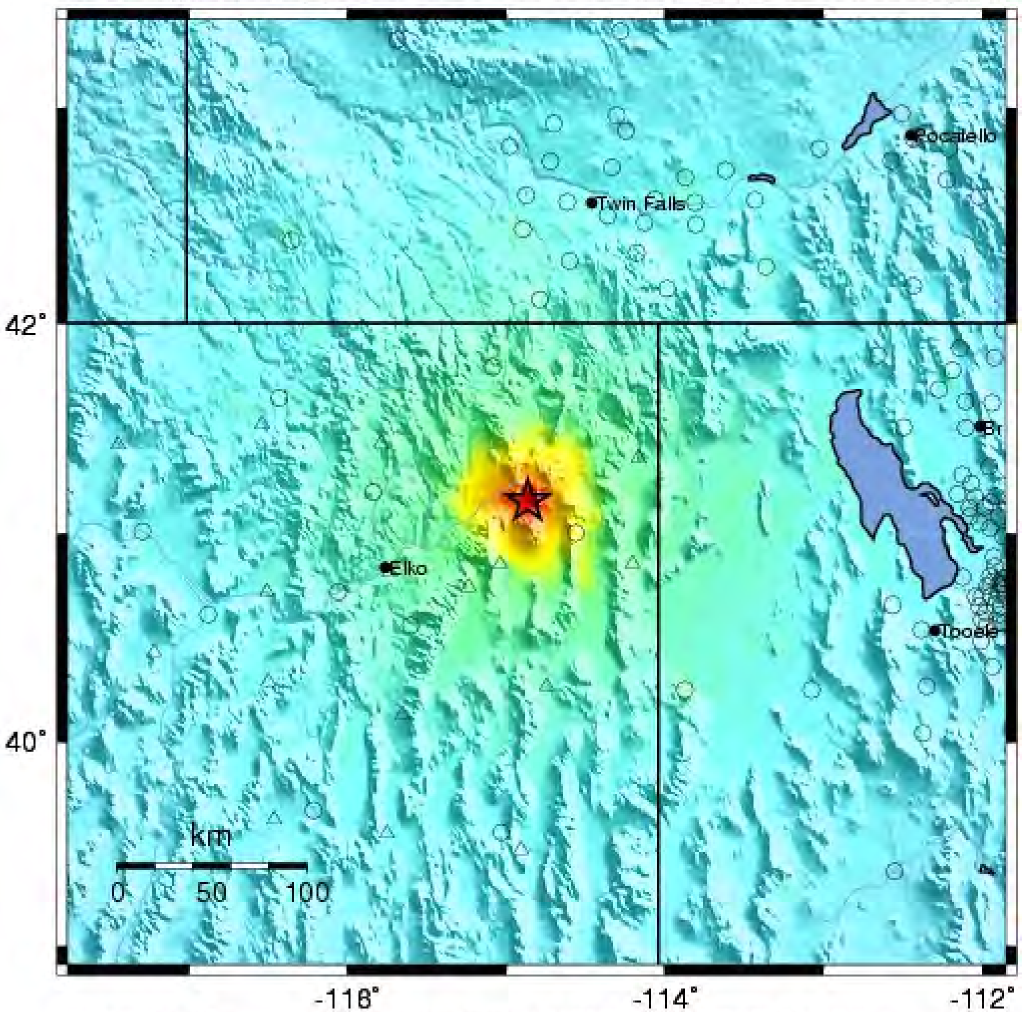




Map of aftershocks as of: 04/01/2008 12:05:44 PM

USGS ShakeMap : NEVADA

Thu Feb 21, 2008 14:16:05 GMT M 6.0 N41.15 W114.87 Depth: 10.0km ID:2008nsa9

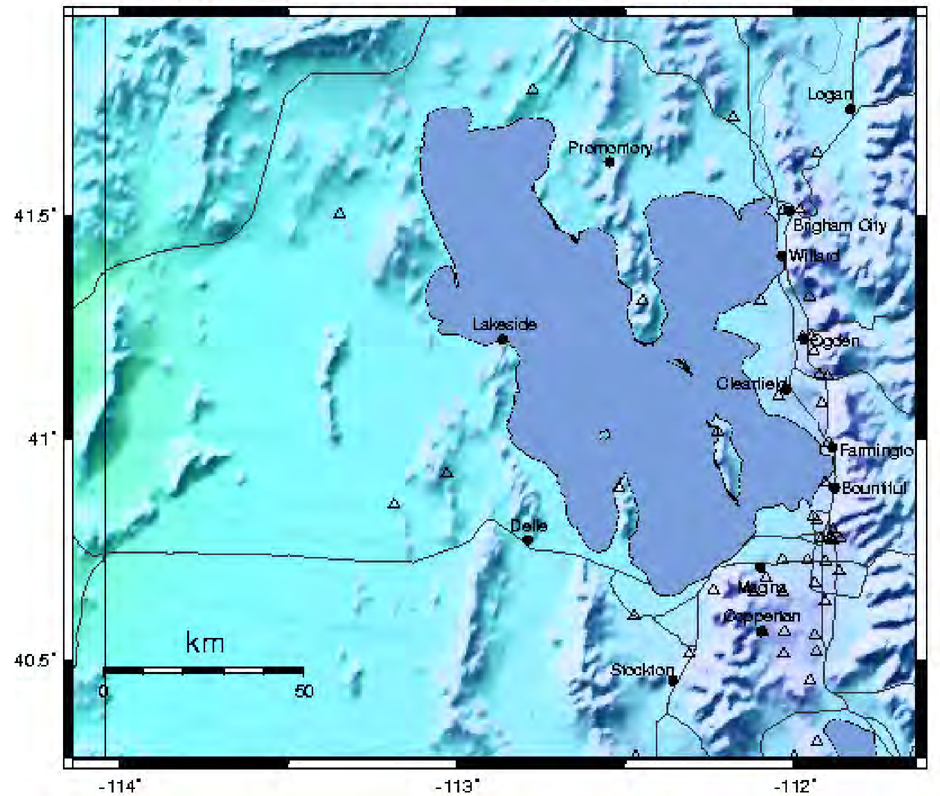


Map Version 10 Processed Mon Mar 17, 2008 01:37:26 PM MDT -- NOT REVIEWED BY HUMAN

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

UUSS ShakeMap for event: 1000012294

Thu Feb 21, 2008 07:16:02 AM MST M 6.0 N41.11 W114.86 Depth: 6.5km ID:1000012294



Map Version 1 Processed Thu Feb 21, 2008 07:23:26 AM MST, -- NOT REVIEWED BY HUMAN

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
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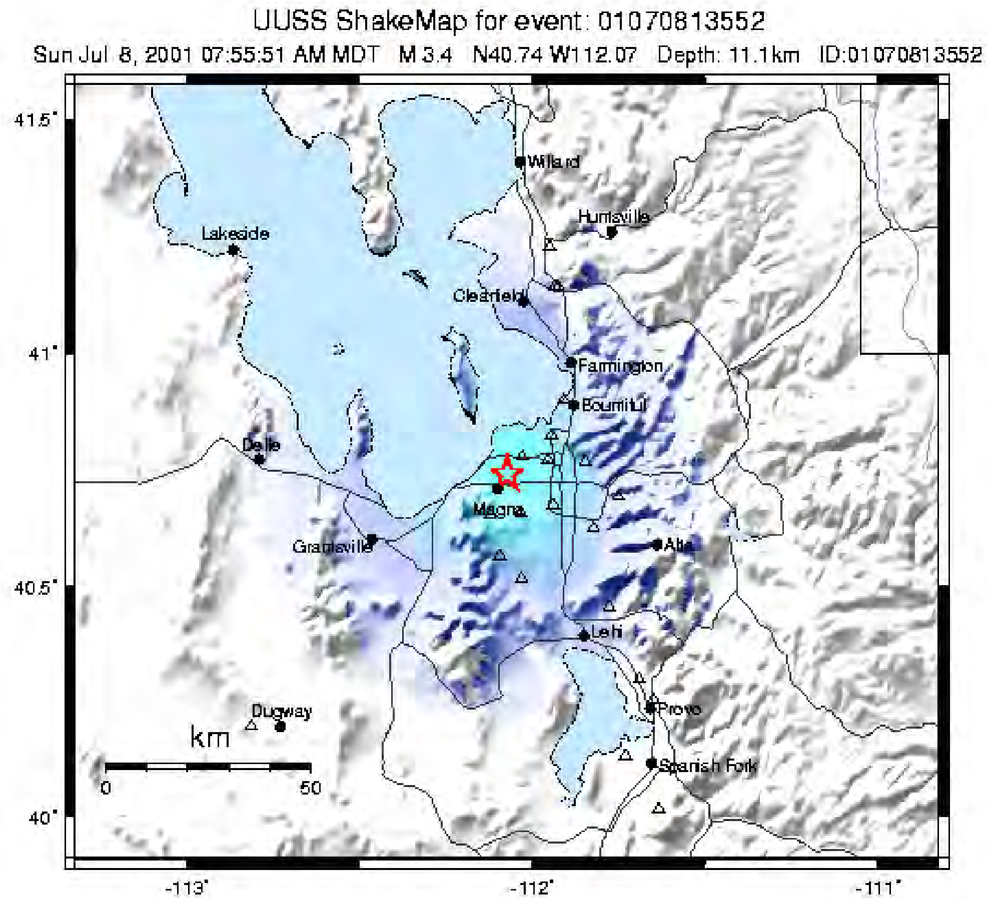
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

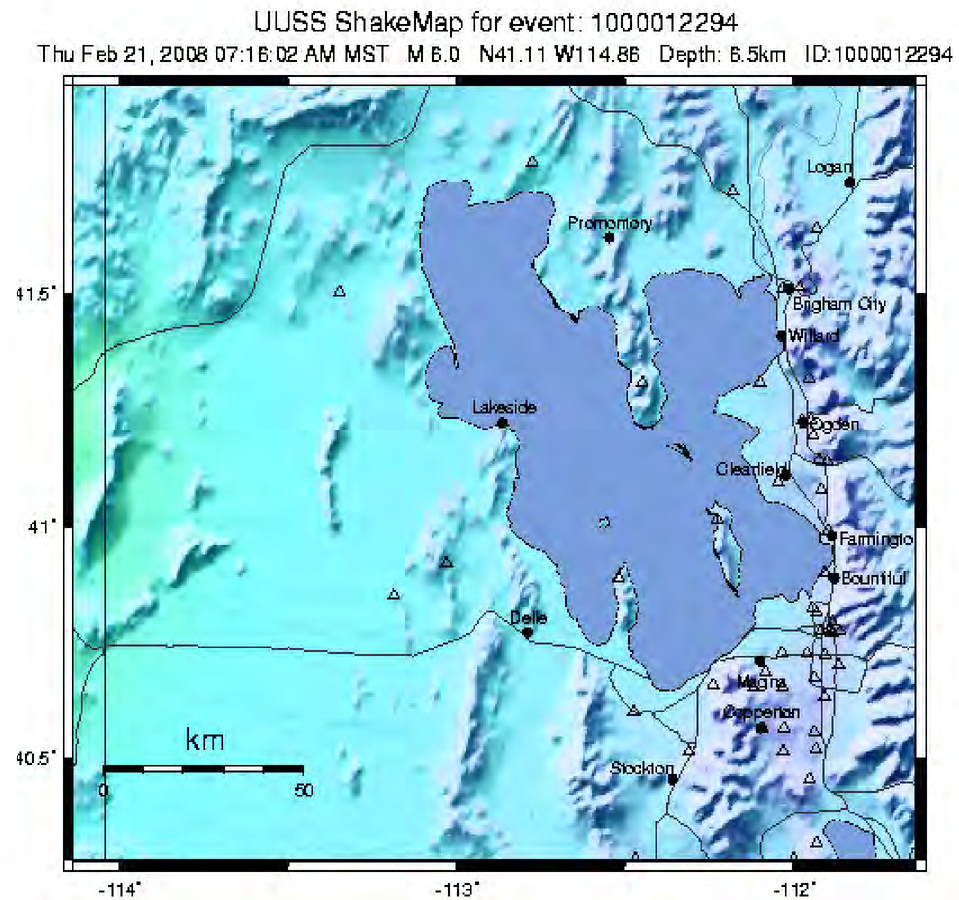
2001 Magna Earthquake



Map Version 4 Processed Thu Mar 30, 2006 02:49:22 PM MST,

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

2008 Wells, NV Earthquake

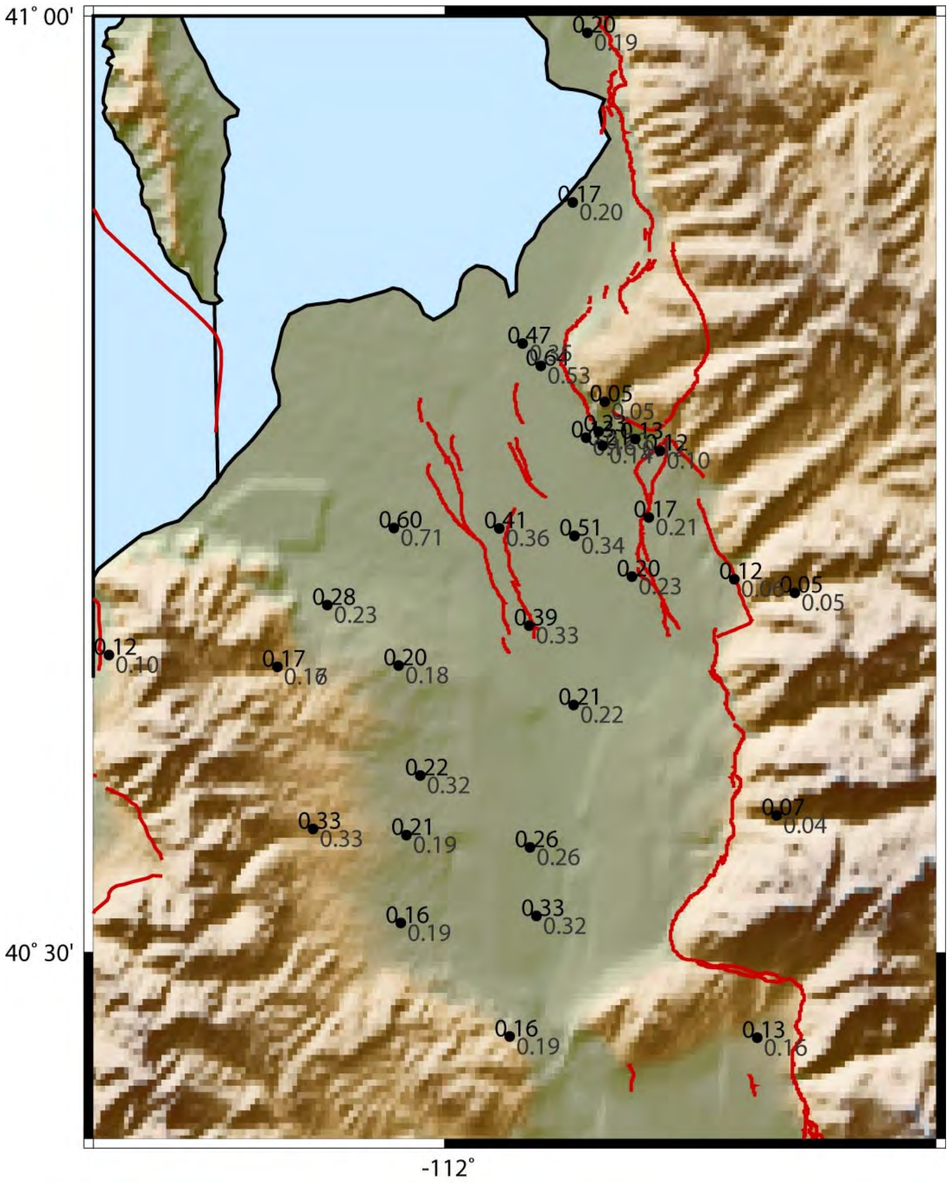


Map Version 1 Processed Thu Feb 21, 2008 07:23:26 AM MST, -- NOT REVIEWED BY HUMAN

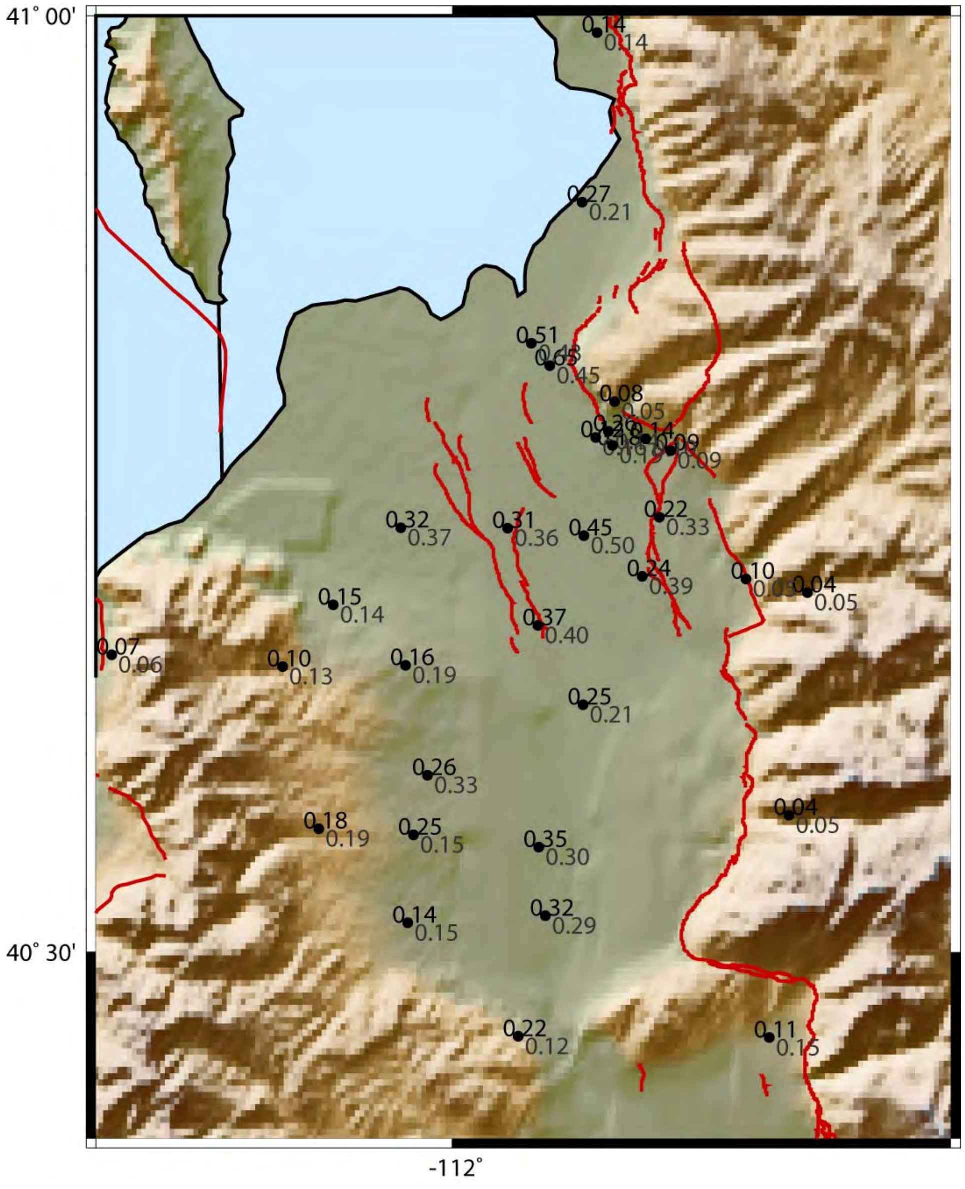
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Peak Ground Motions

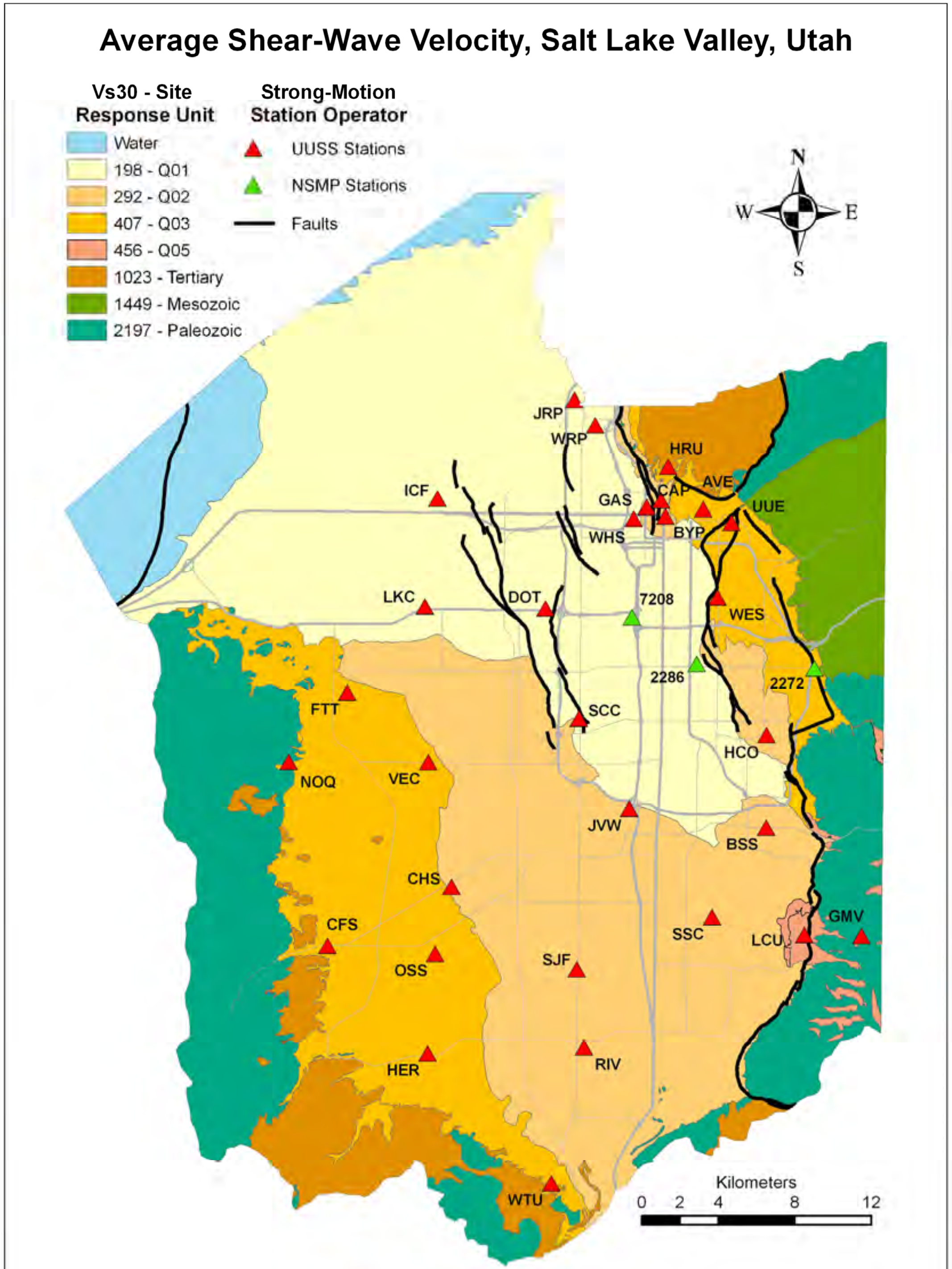
PGA (% g)



PGV (cm / s)



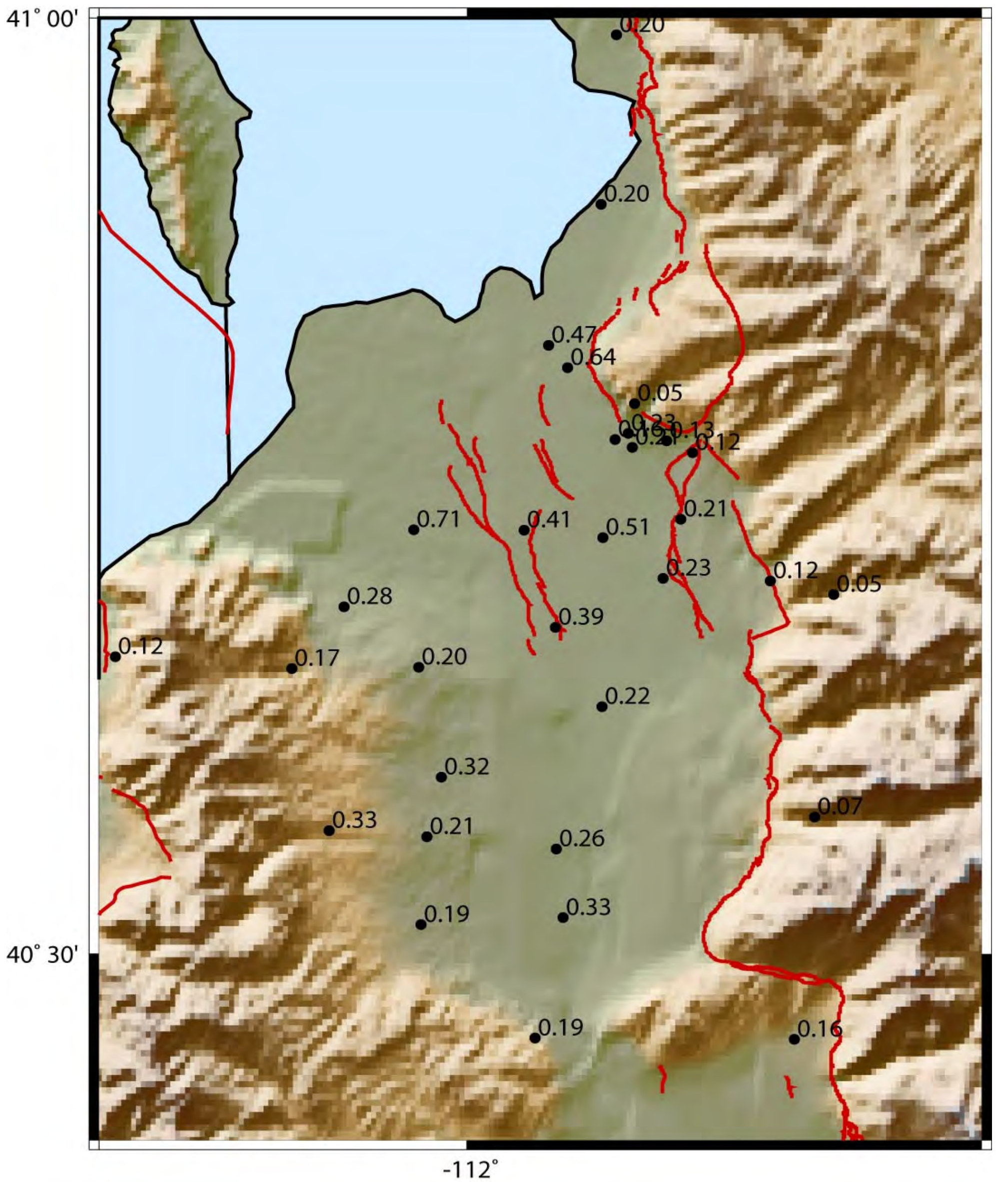
Site Response Map



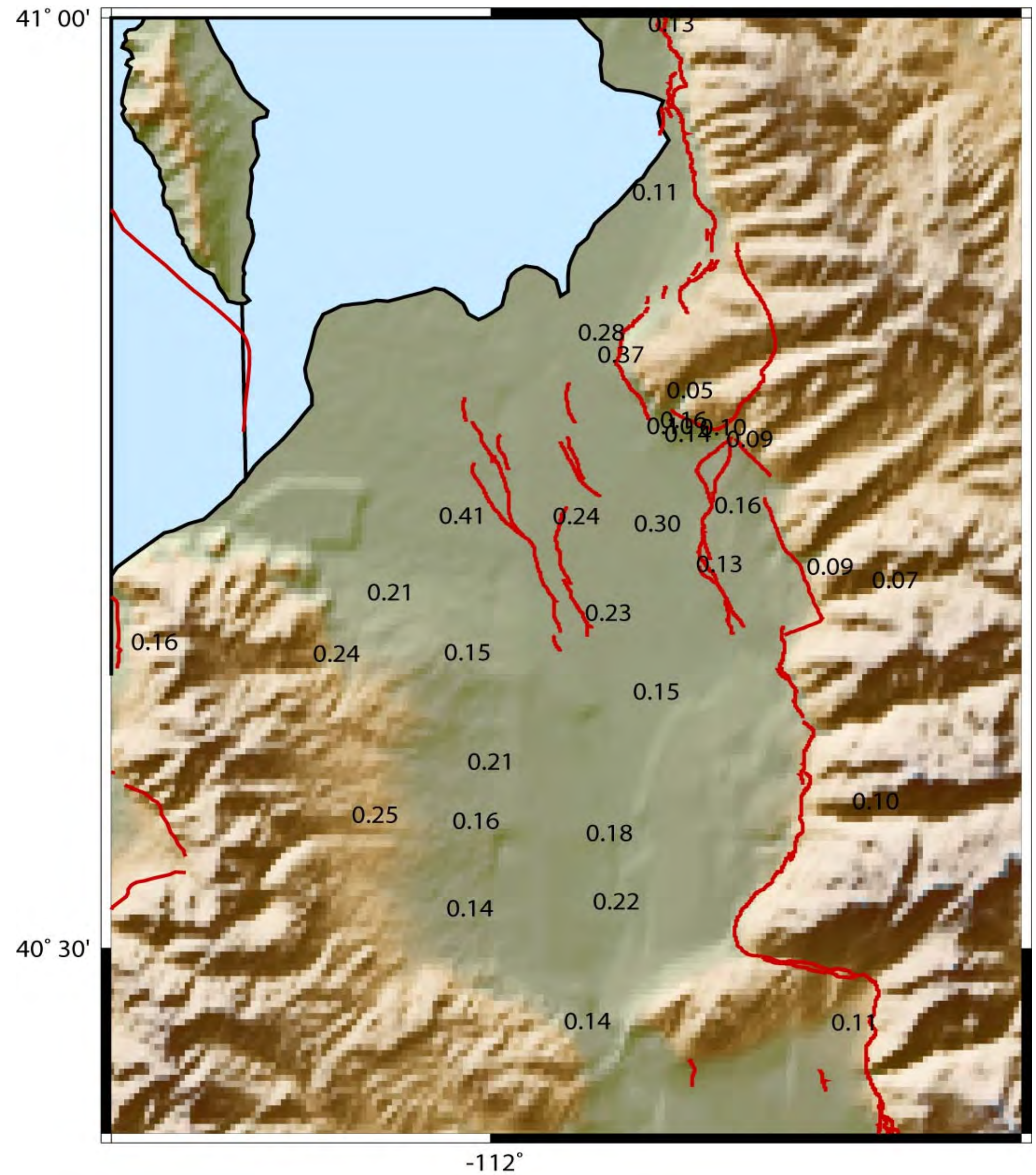
Adapted from Bay, J., F.X. Ashland and K.L. Pankow (2004). Shallow shear wave velocity profiling of poorly characterized earthquake site response units in urban Salt Lake Valley, NEI-IRP Final Technical Report.
Ashland, F.X. and G.N. McDonald (2003). Interim map showing sheer-wave-velocity characteristics of engineering geologic units in the Salt Lake City, Utah, metropolitan area, Utah Geological Survey, Open-File Report 424, 44pp.

Maximum PGA

PGA (%g)

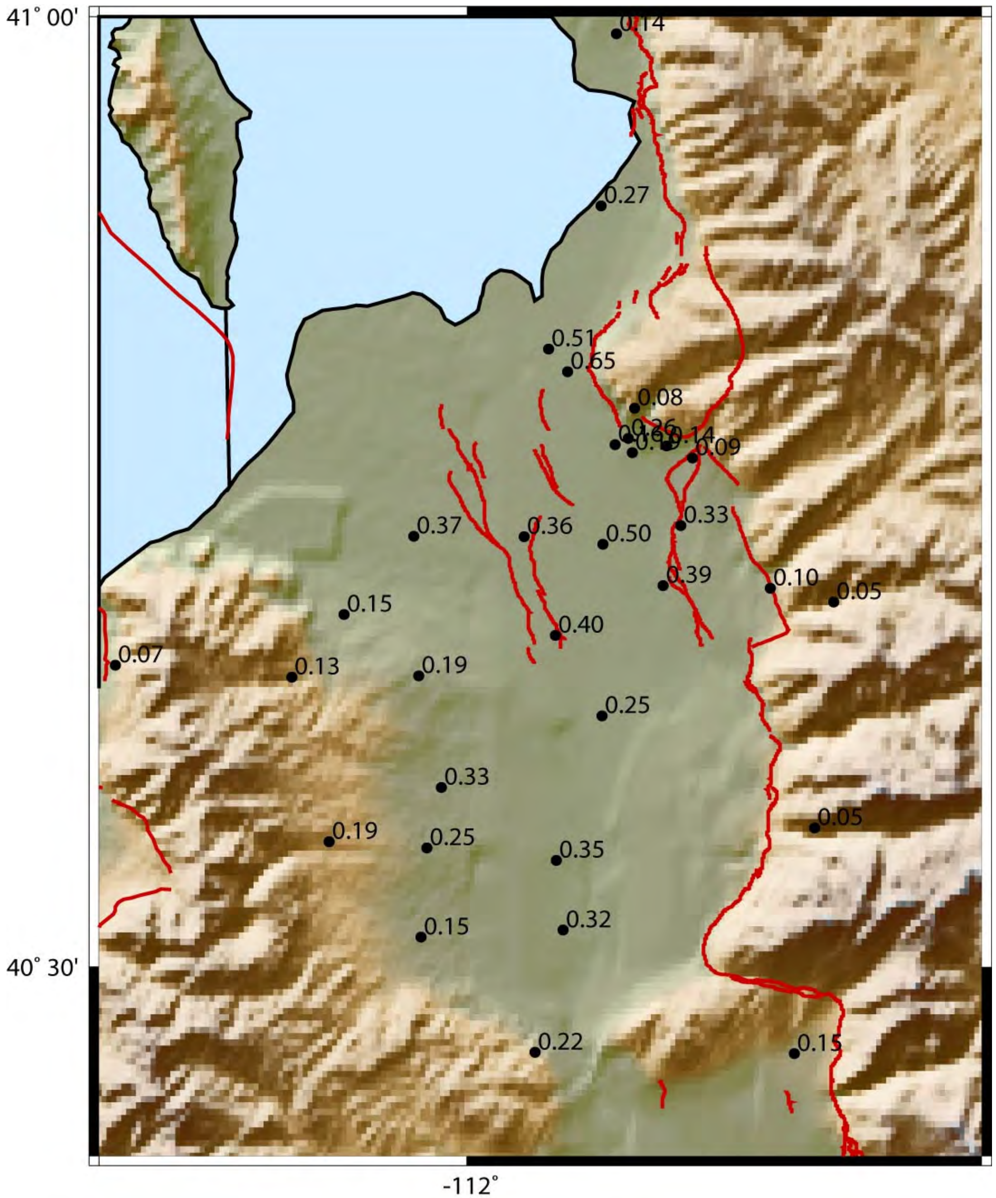


Corrected

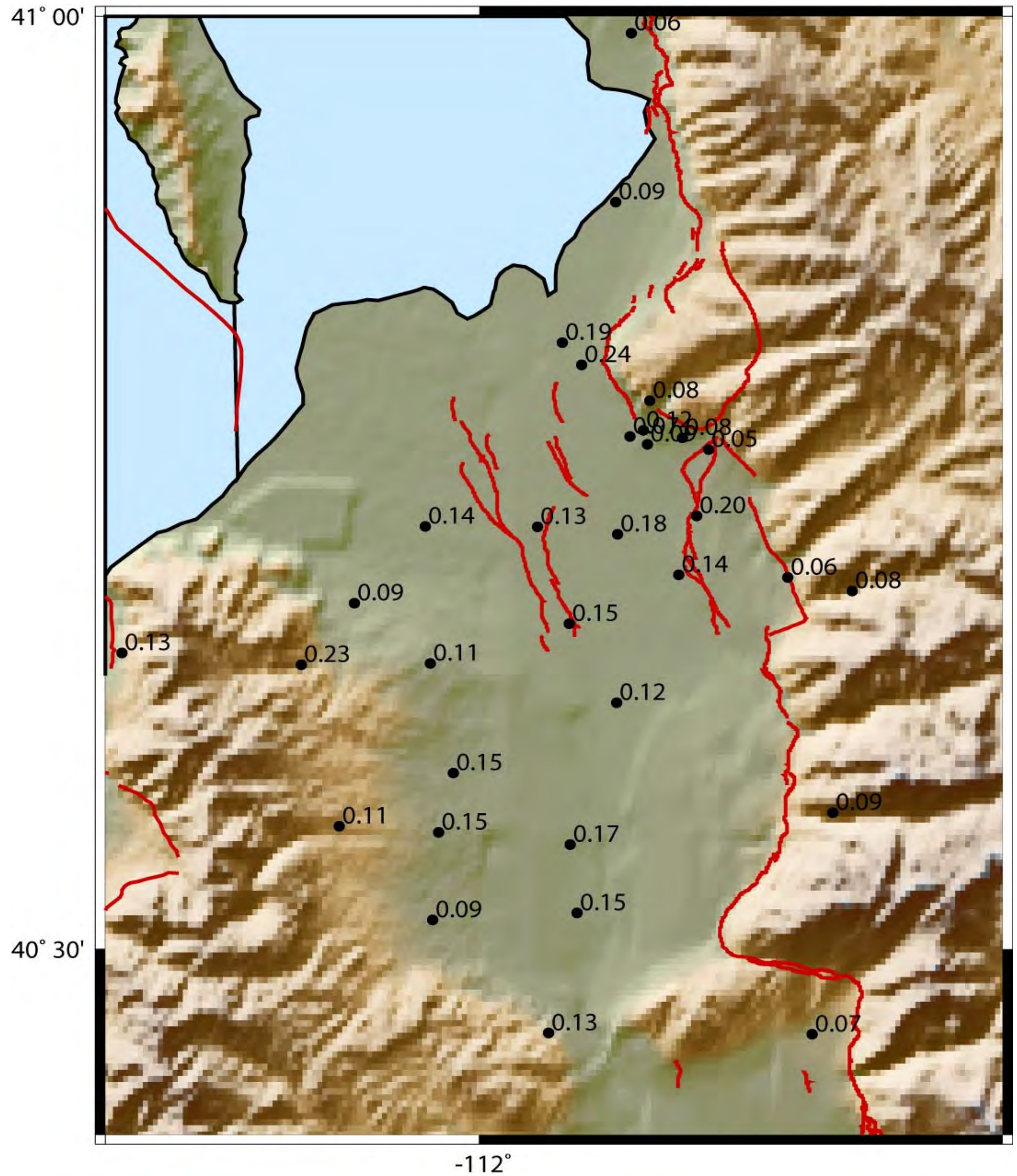


Maximum PGV

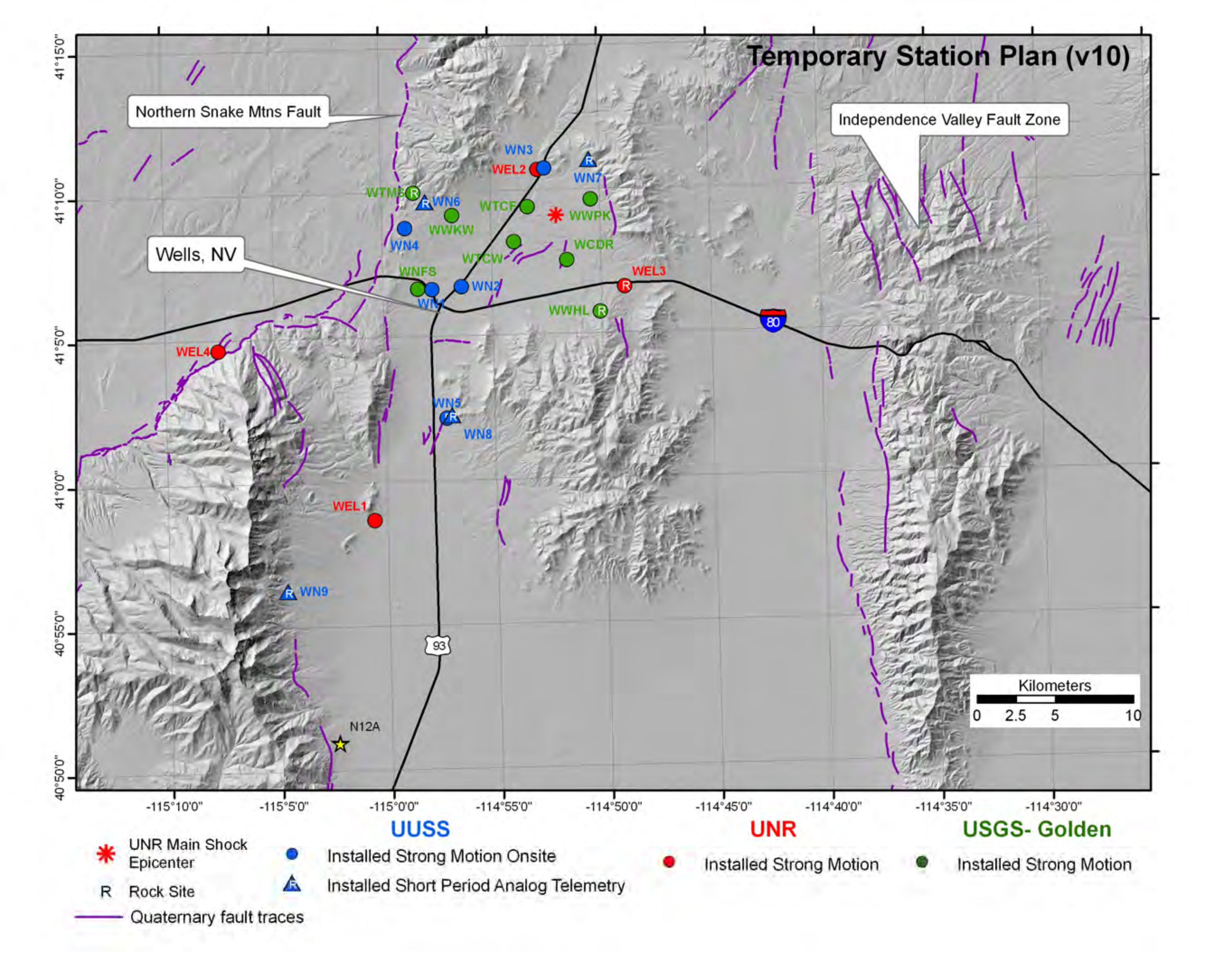
PGV cm / s)

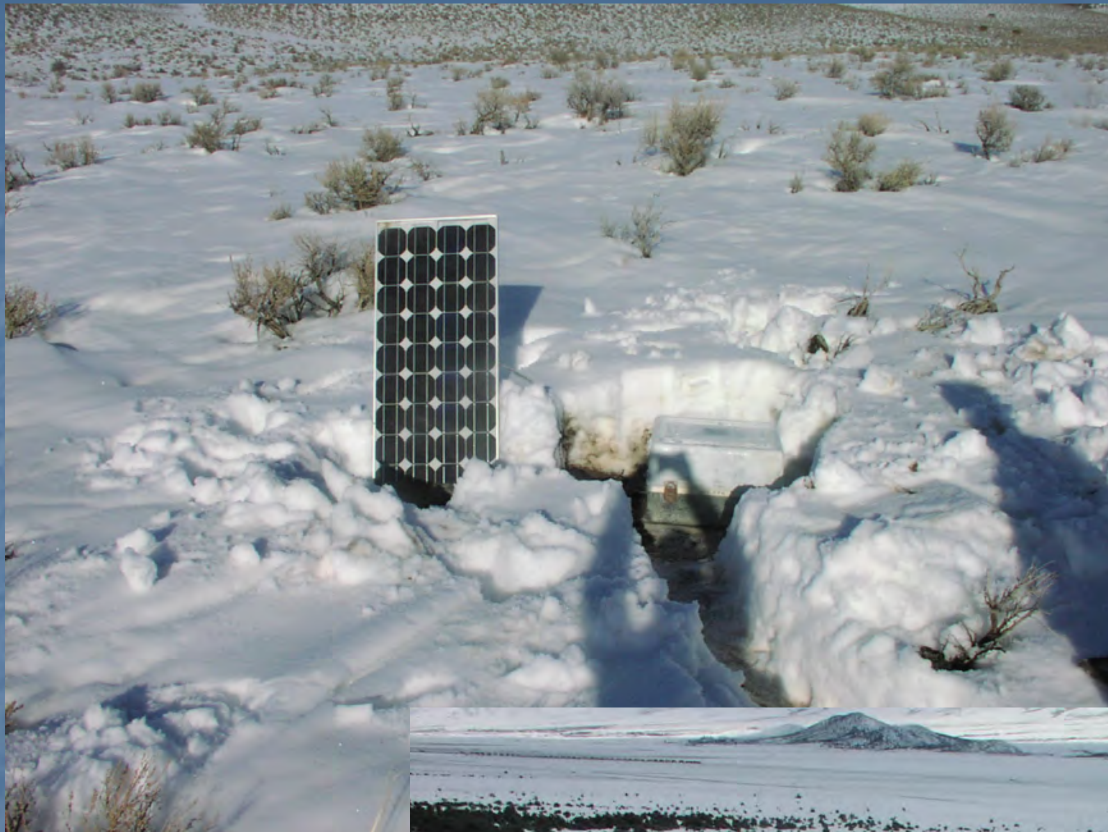


Corrected



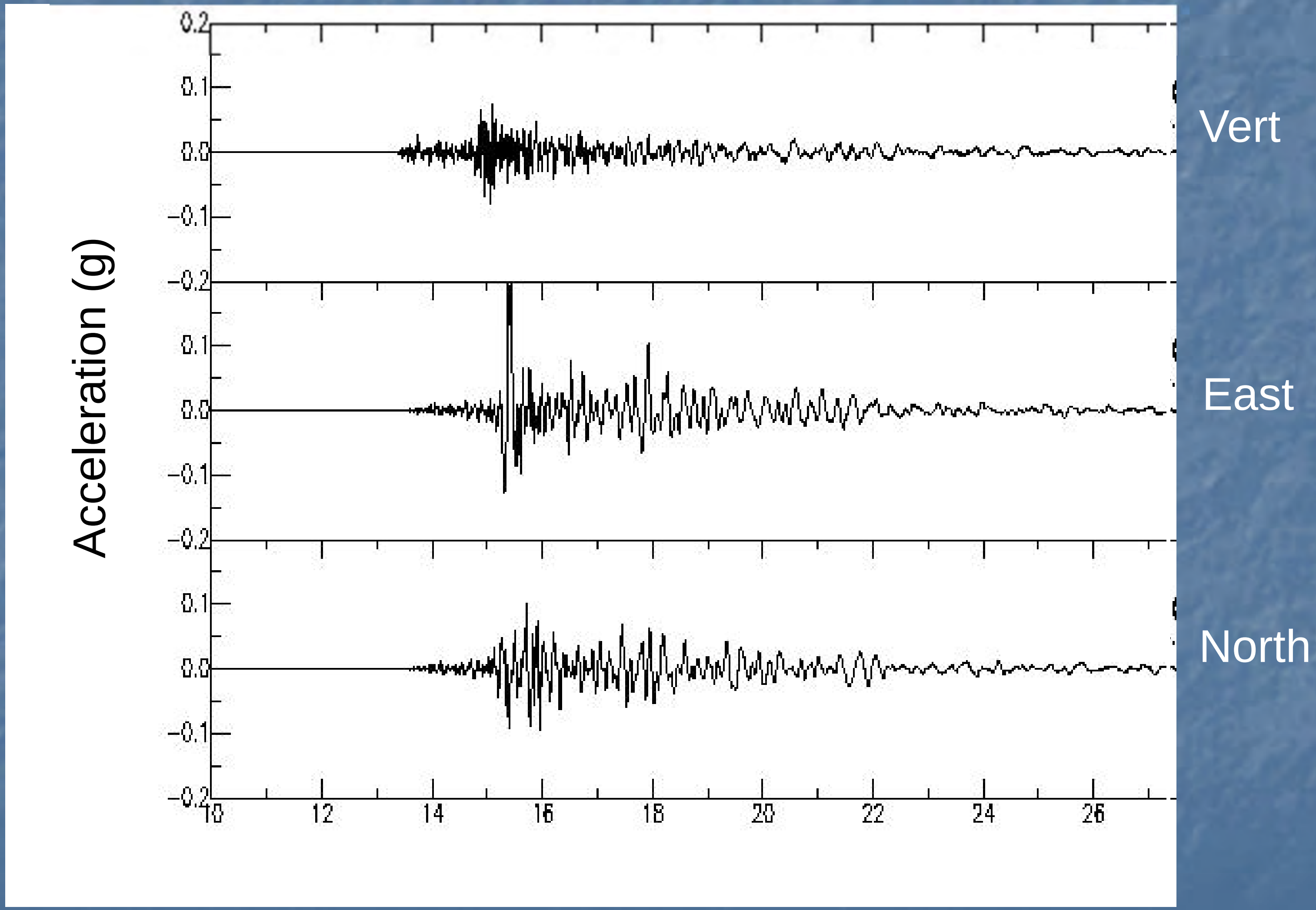
Instrument Deployment





M4.7 Wells Aftershock

Recorded at Wells Fire Station



M4.7 Wells Aftershock

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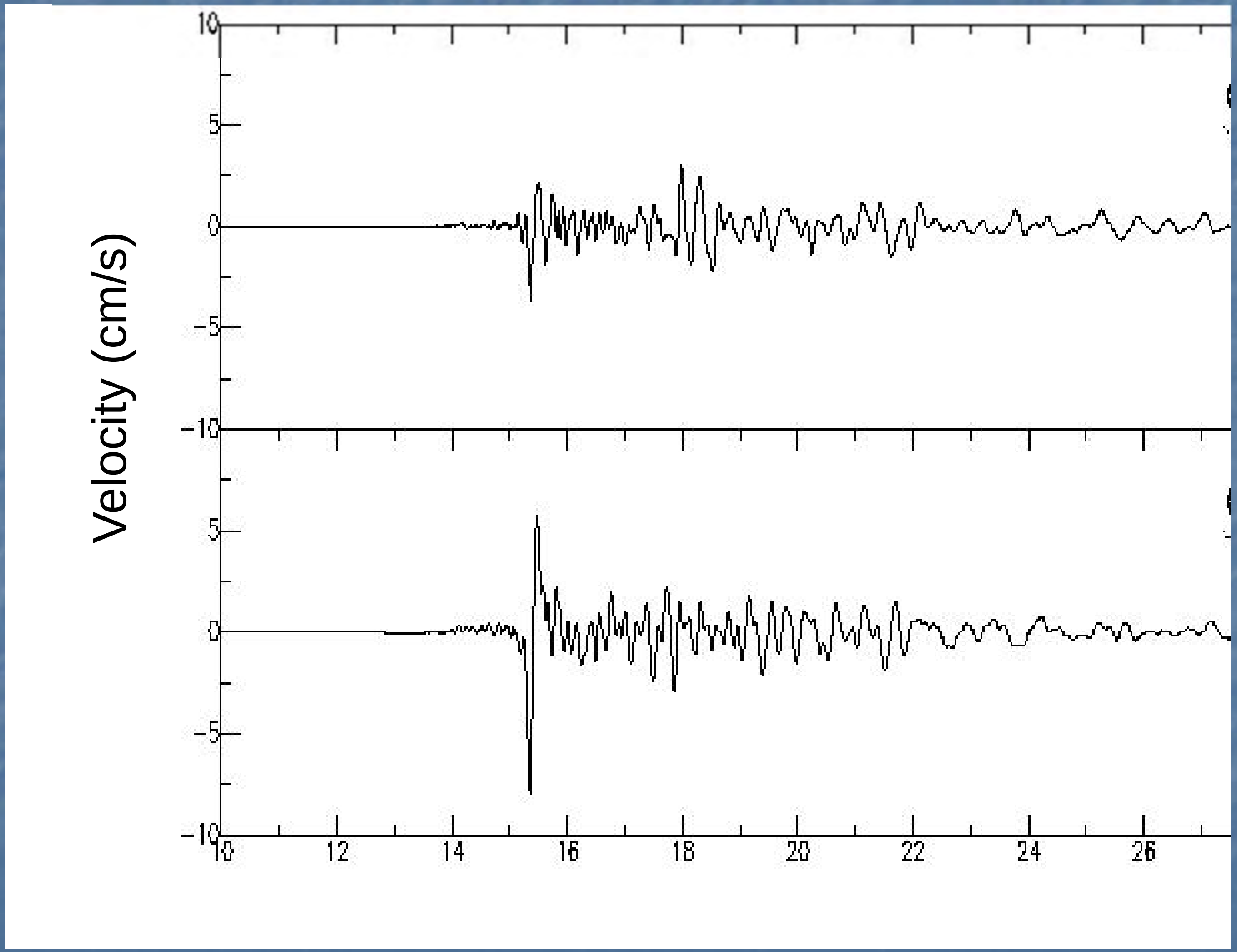
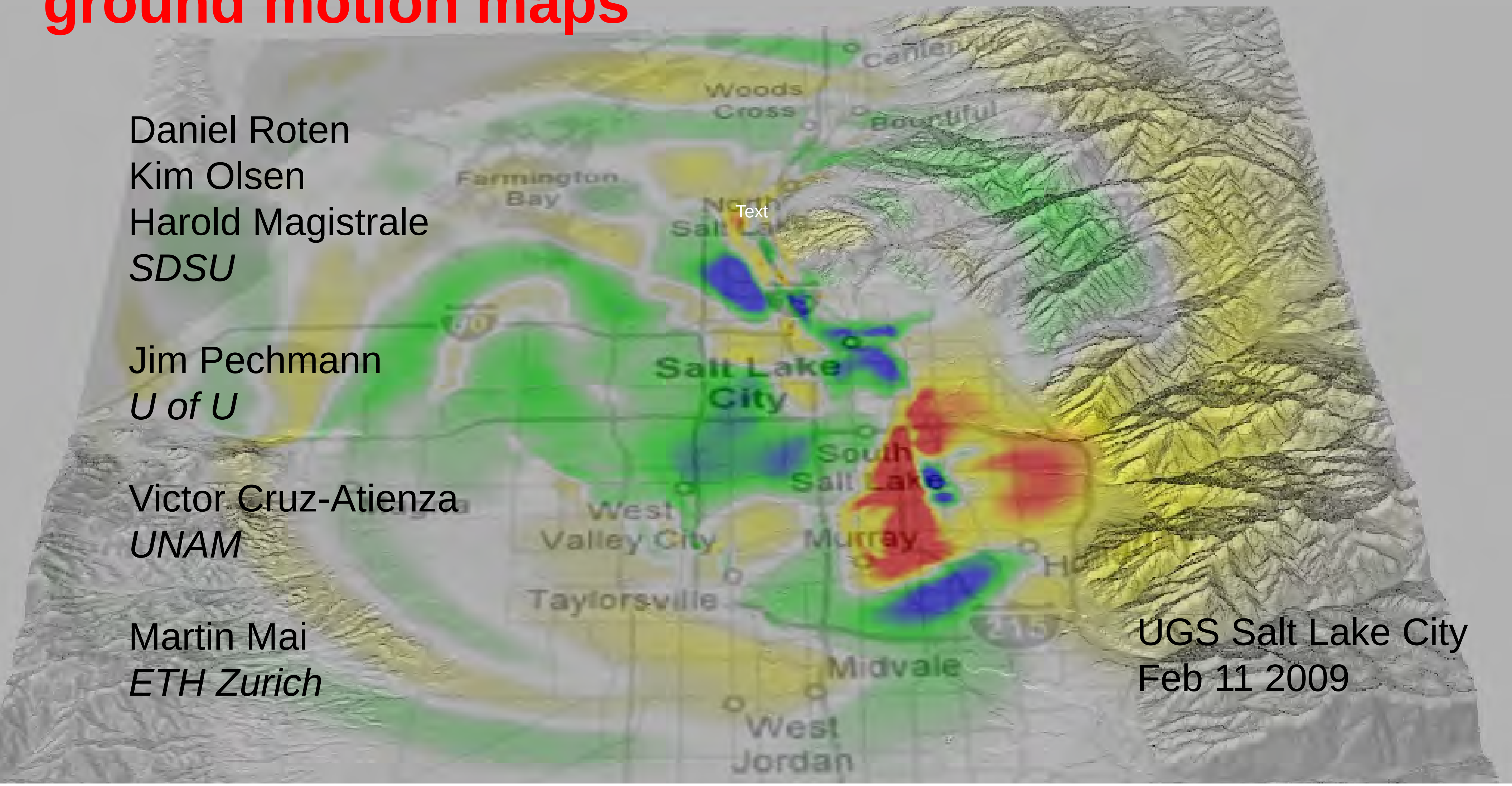


Presentation and discussion of Wasatch Front community velocity model (CVM) validation

Preliminary 1Hz 3-dimensional M7.0 scenario ground motion maps



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UGS Salt Lake City
Feb 11 2009

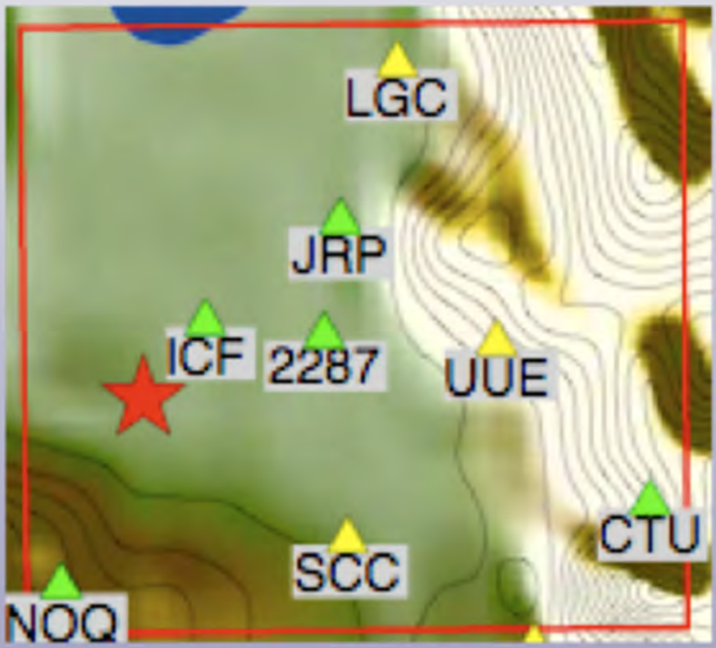
Outline

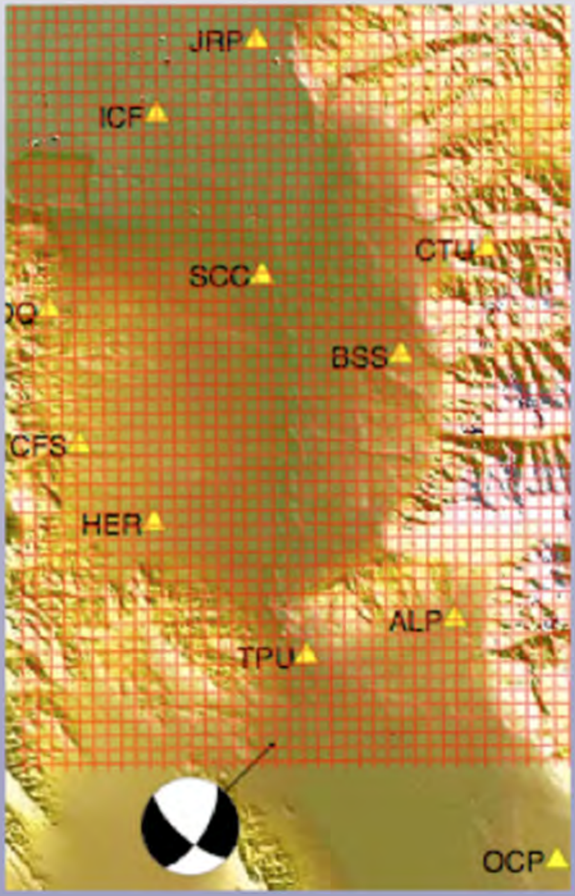
- **Review of WFCVM validation**
- **Generation of a 3-D model of the Wasatch fault**
- **M7 rupture models**
  - Pseudo-dynamic rupture models
  - Dynamic rupture models
  - Method for projecting planar rupture models onto irregular WF
- **Results of 0-1 Hz 3-D FD simulations**
  - PGVs and SAs obtained from dynamic and pseudo-dynamic rupture models
  - Synthetic seismograms at selected sites
  - Average 1s-SAs compared to Solomon et al (2004) and empirical attenuation models
- **Generation of broadband (0-10 Hz) synthetics**
  - Method
  - Results - SAs and synthetic seismograms at selected sites
- **Conclusions**

Review of WFCVM Validation

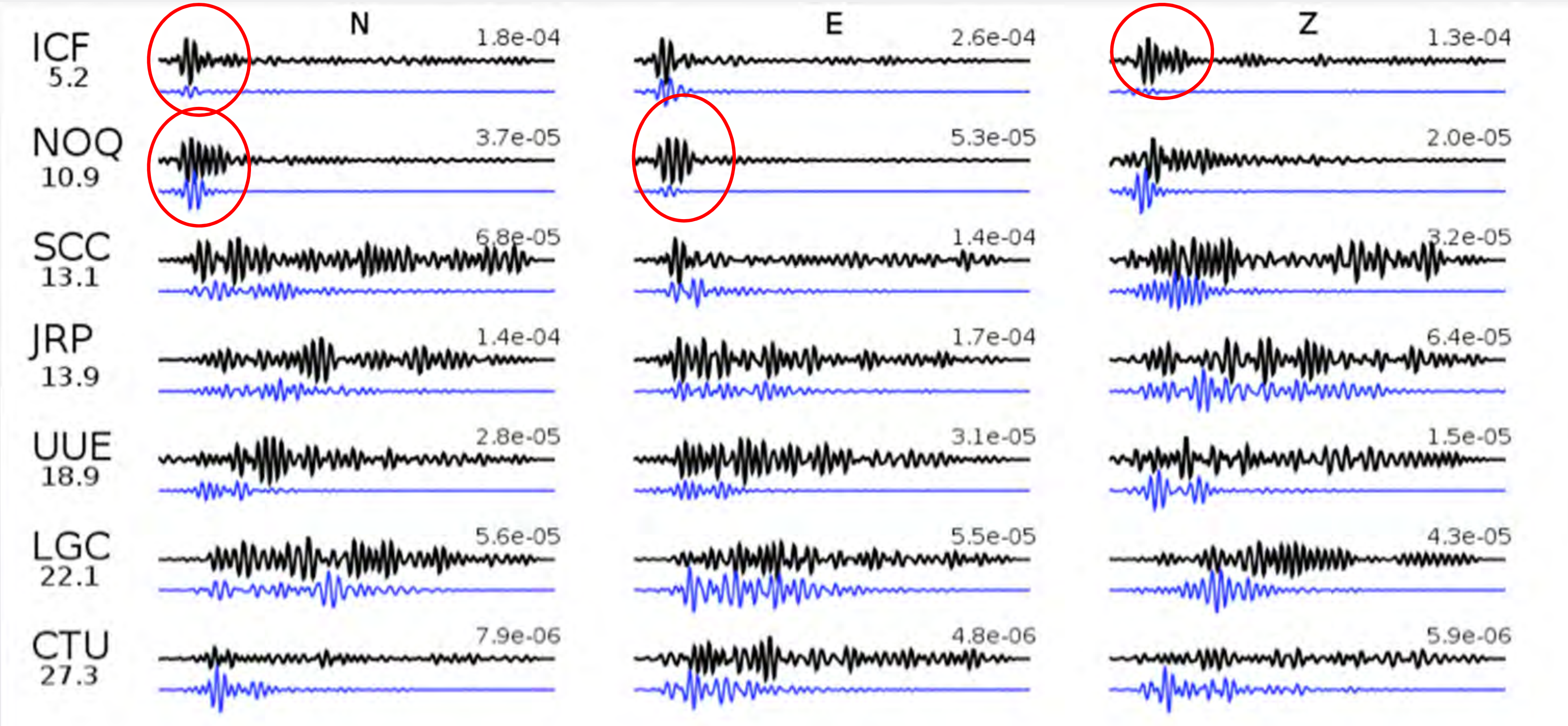
Validation Events

M_L 3.32 Magna 010708, depth = 11.6 km
M_W 3.66 Tremonton 070901, depth = 9 km
M_L 3.30 Lehi 010524, depth = 8.9 km

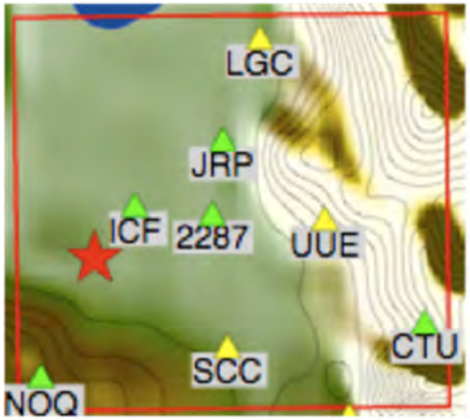




Review of WFCVM Validation



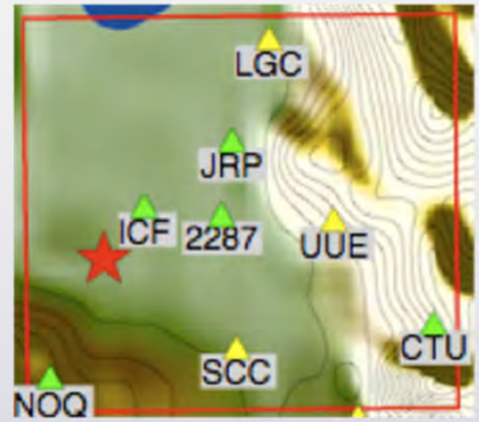
- Striking misfit of waveform amplitudes at stations close to hypocenter
- Source mechanism wrong?

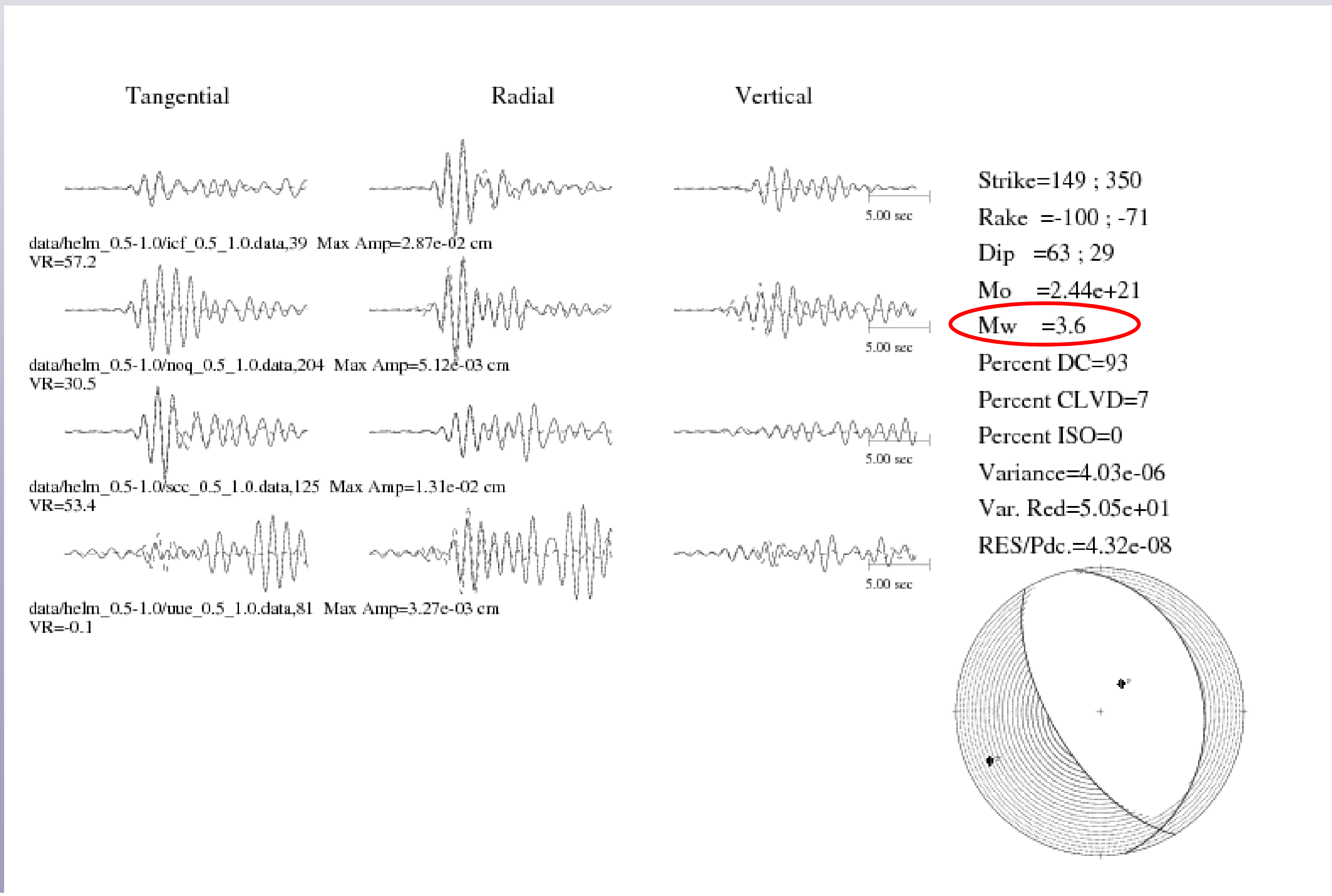


Review of WFCVM Validation

Momemt tensor (MT) inversion of Magna event

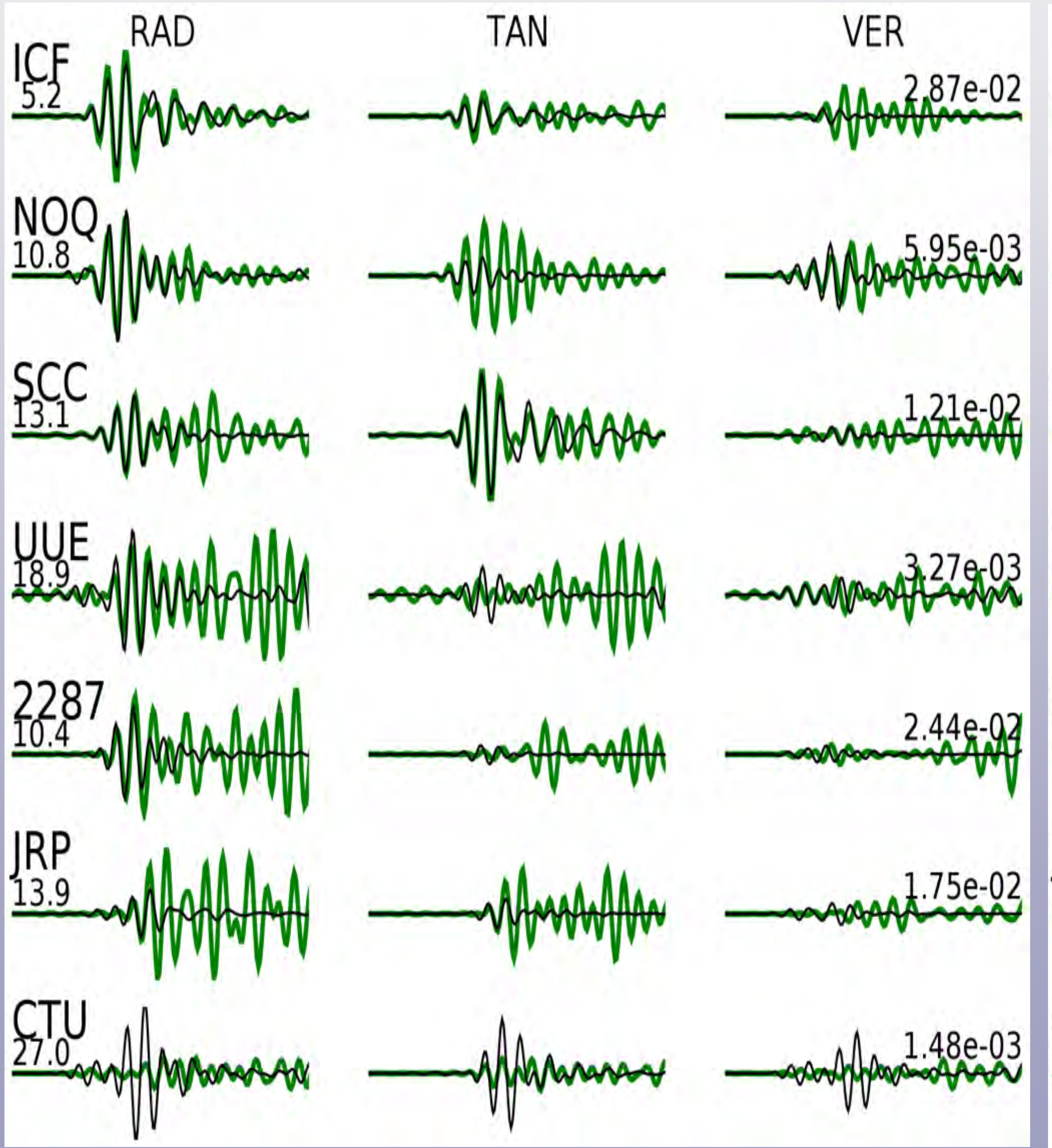
- 4 stations ICF, NOQ, SCC, UUE (seismic gap of > 180°)
- Green's function computed from 1-D column extracted from WFCVM below respective station
- Topography included by adjusting depth
- Frequency band from 0.5 to 1.0 Hz
- MT inversion code by Dreger (2003)



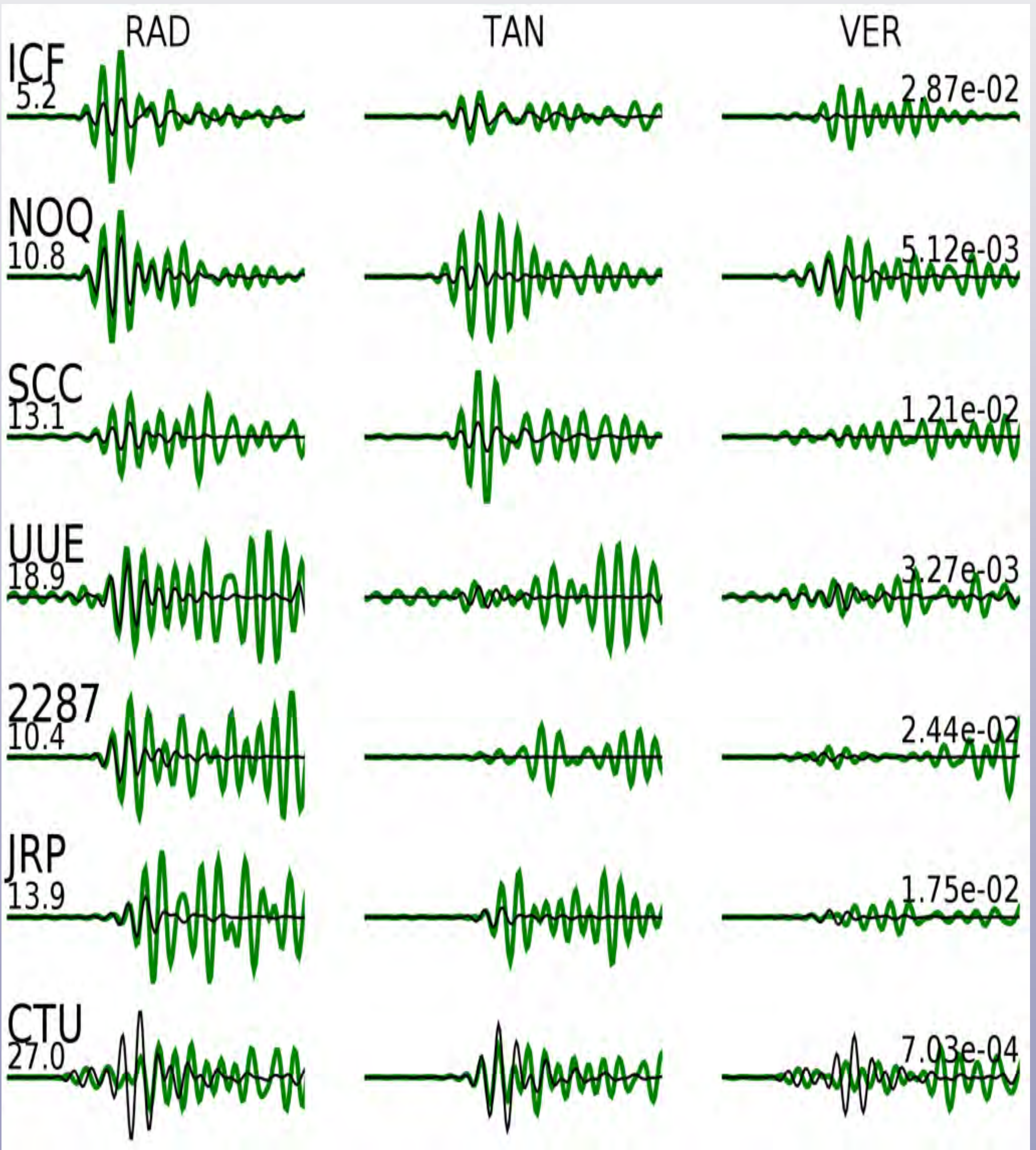


Review of WFCVM Validation

Observed (**green**) and synthetic (black) waveforms obtained from convolution of 2-D Green's functions with mechanism from MT inversion

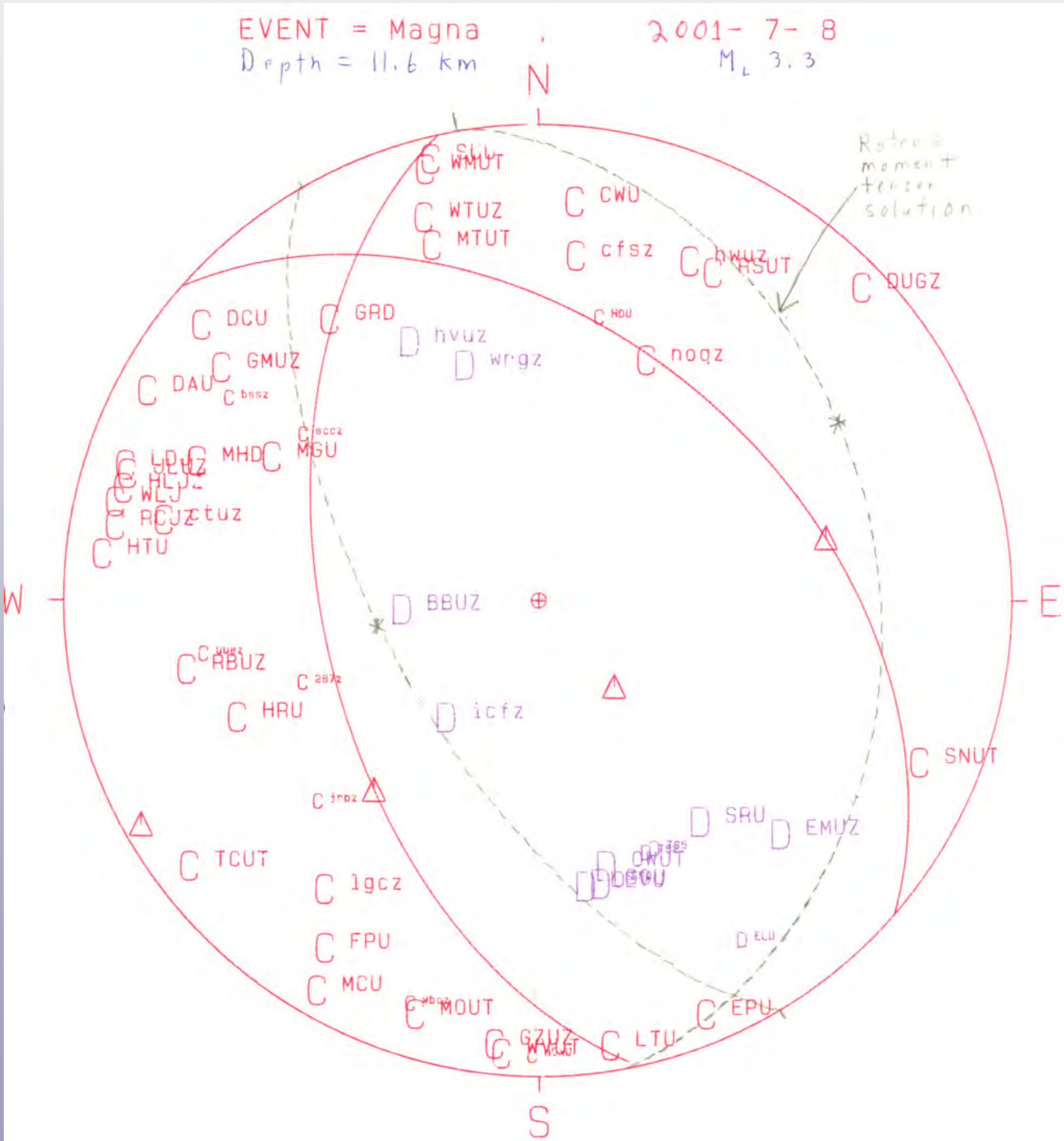


Observed (**green**) and synthetic (black) waveforms obtained from convolution of 2-D Green's functions with first-motion source mechanism



Review of WFCVM Validation

First-motion plot from Magna event

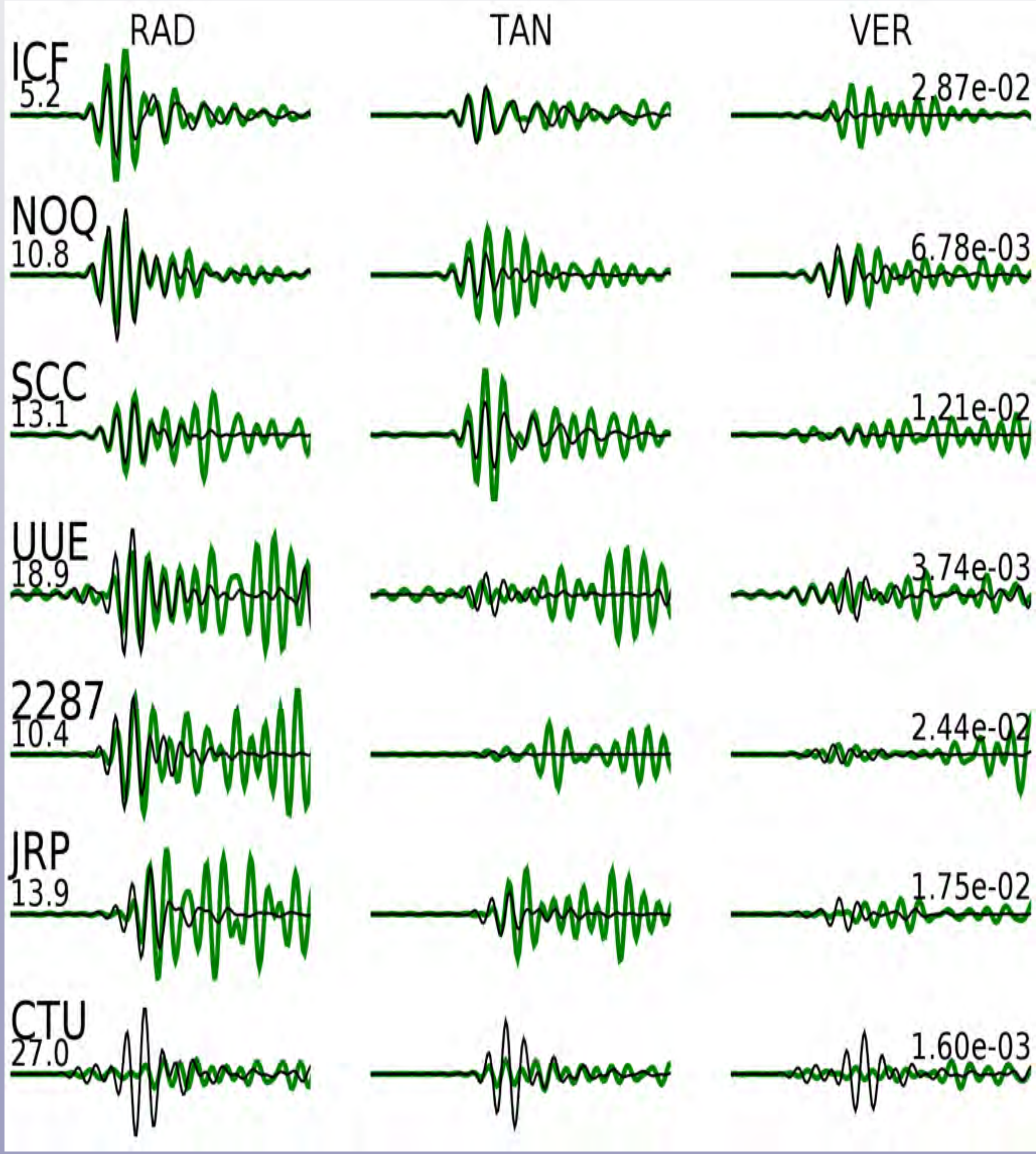


Source mechanism obtained from MT inversion must be rejected from first-motion data

So why does the forward computation with the mechanism from the MT-inversion yield a better waveform fit?

Review of WFCVM Validation

Observed (**green**) and synthetic (black) waveforms obtained from convolution of 2-D Green's functions with mechanism from first-motion, but using M_w=3.6

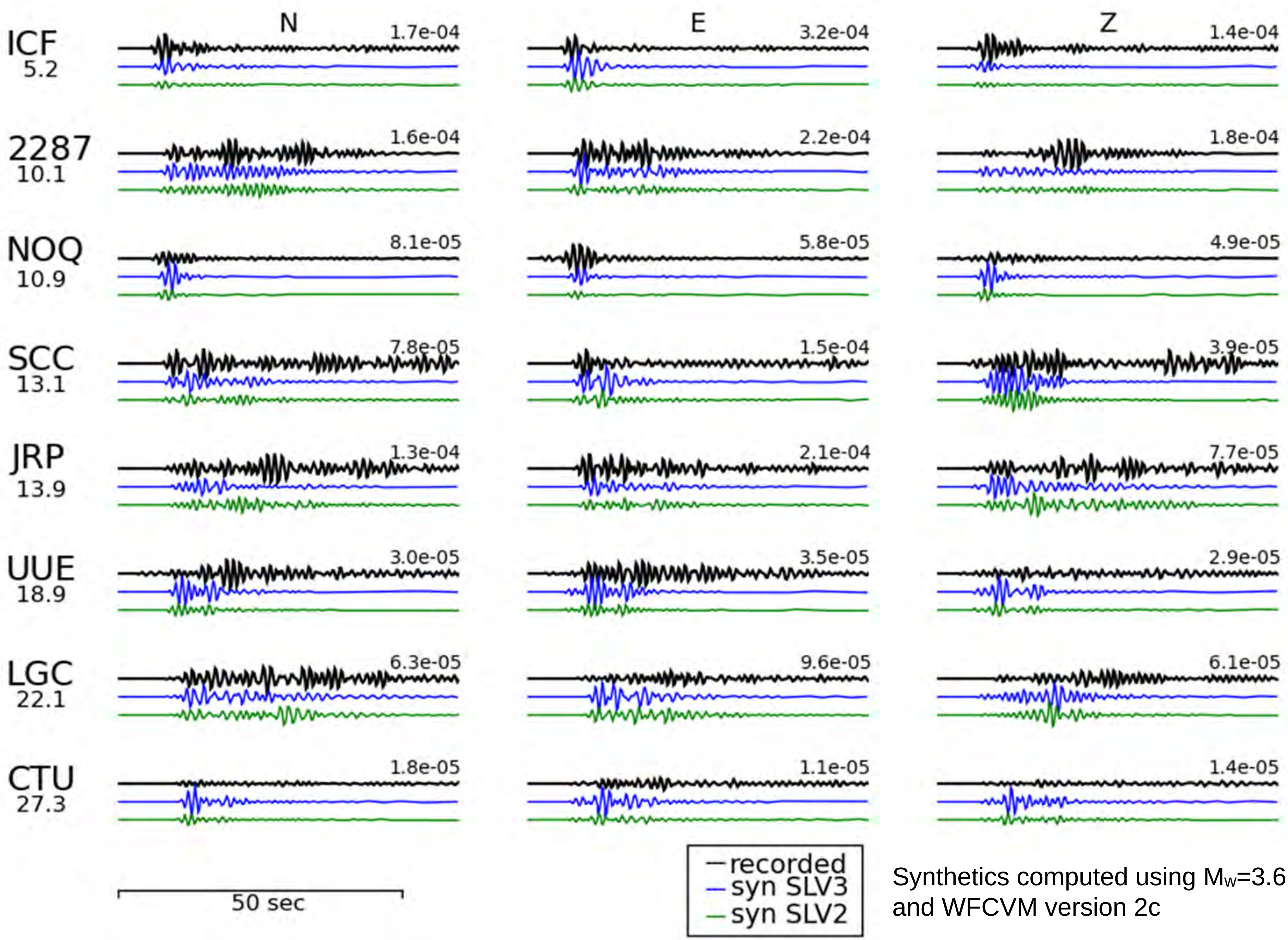


Increasing M_w from 3.3 to 3.6 does significantly improve the fit, especially at close-range stations

Overestimation of amplitude at more distant rock site CTU

Similar results found for Lehi event, where MT inversion yields M_w=3.6 (M_L=3.3)

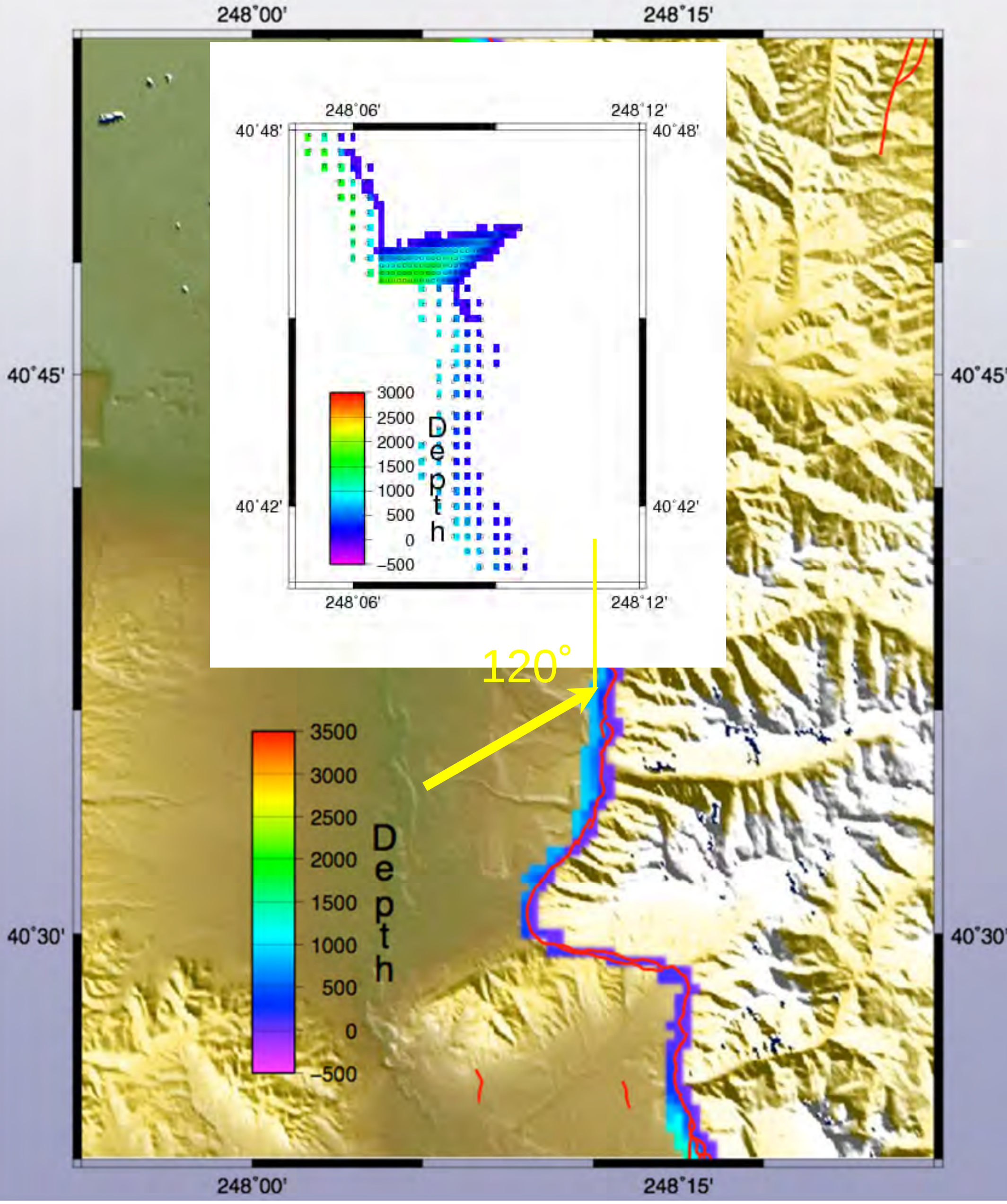
Review of Magna event

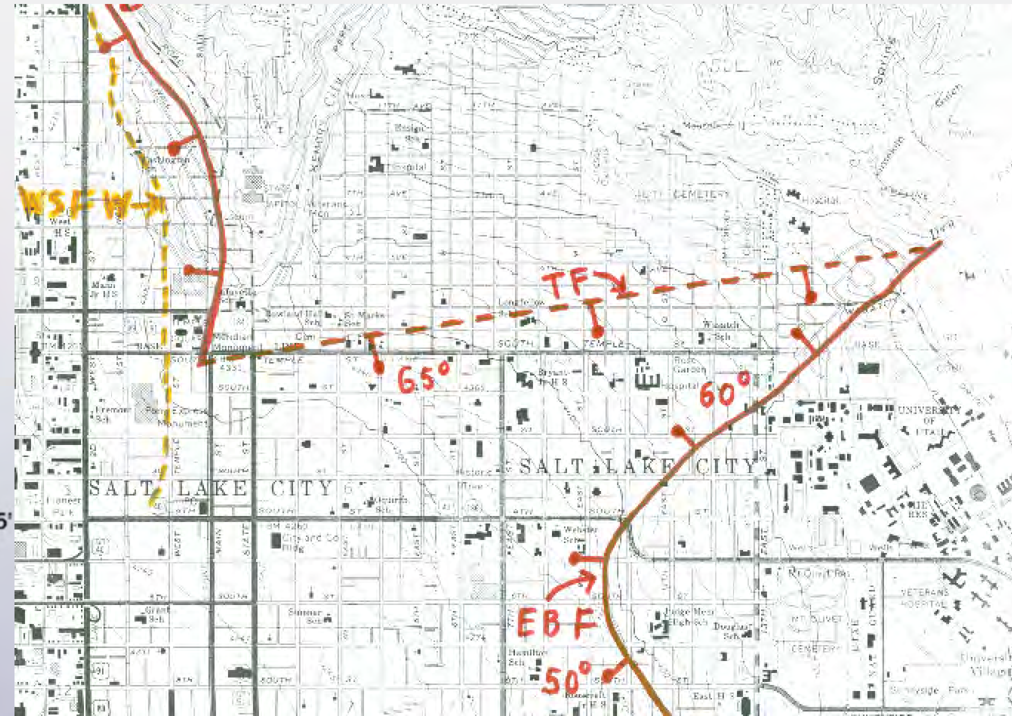


Synthetics computed using M_W=3.6 and WFCVM version 2c

Generation of a 3-D Model of the Wasatch Fault

Fault definition in WFCVM (based on fault model from Bruhn et al., 1992)

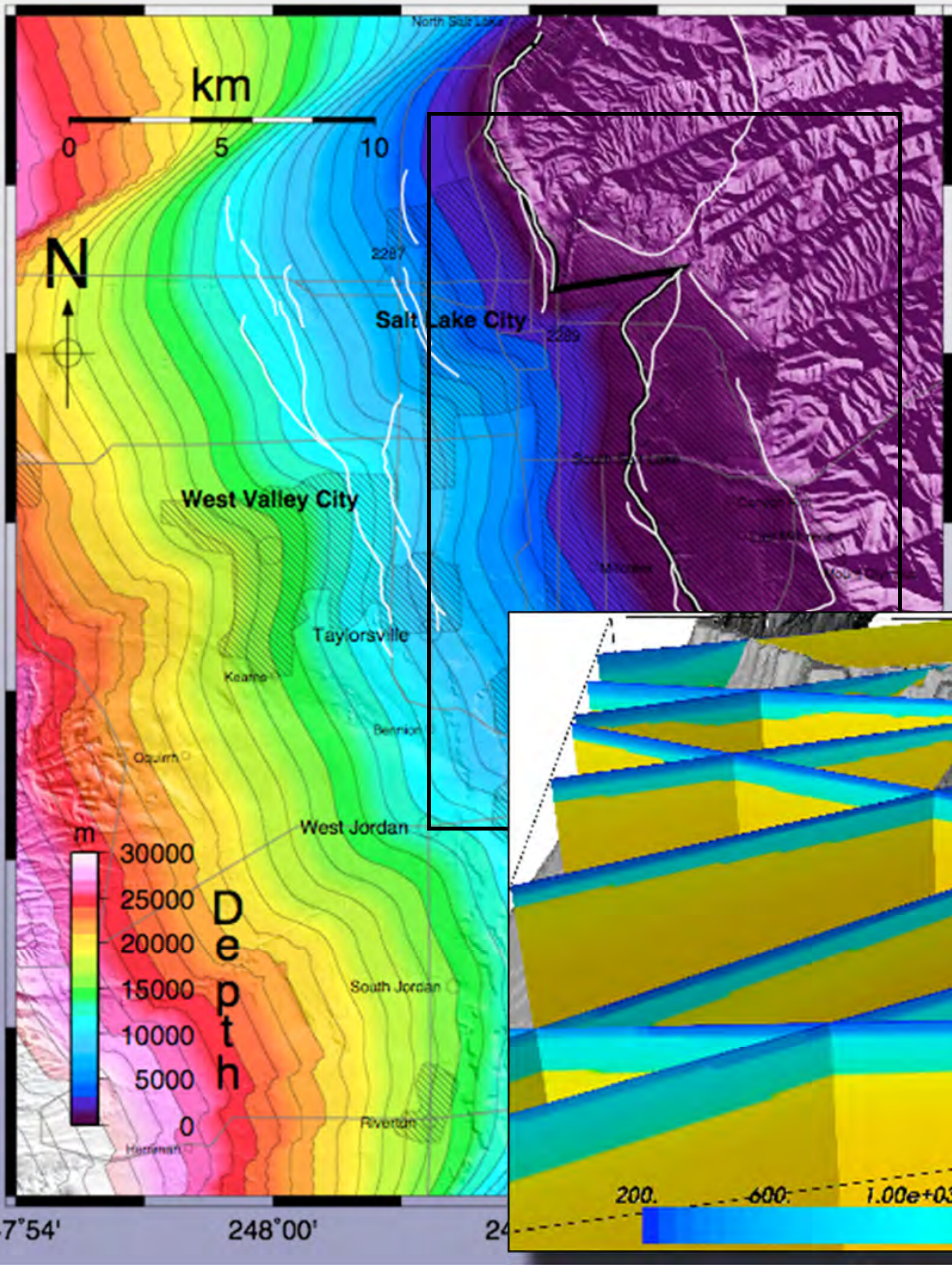


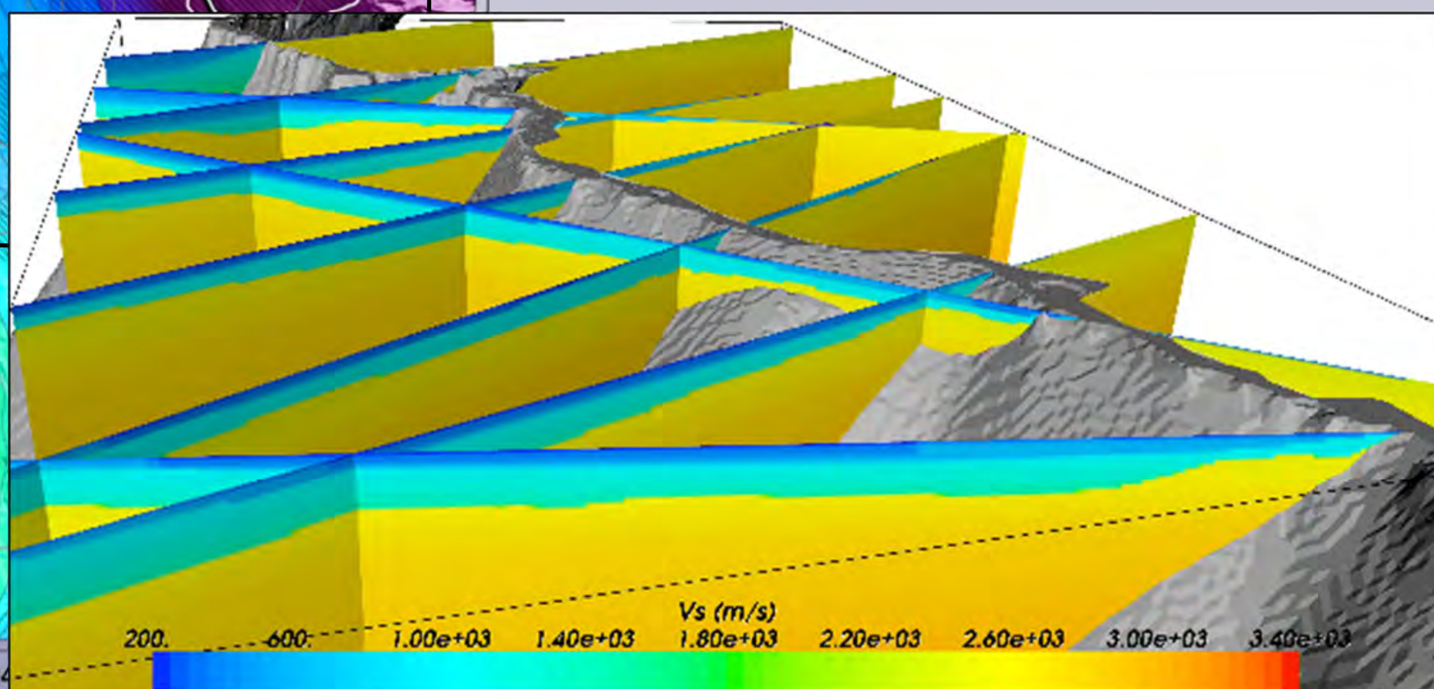


- Tearfault connecting Warm Springs segment and East Bench segment of the WF
- Redefinition of fault and basins in this area

Generation of a 3-D Model of the Wasatch Fault

- Final model of the SLC segment of the WF used for M7 scenario simulations
- Fault geometry mostly consistent with eastern boundaries of the Salt Lake Valley basin





M7 Rupture Scenarios

We use two different approaches to create rupture models on a planar fault:

Pseudo-dynamic (PD) rupture models

- Kinematic models which emulate important characteristics of dynamic rupture

(Guatteri M, Mai M. and Beroza, G., 2004. *A Pseudo-Dynamic Approximation to Dynamic Rupture Models for Strong Ground Motion Prediction*, BSSA, **94** (6), 2051–2063)

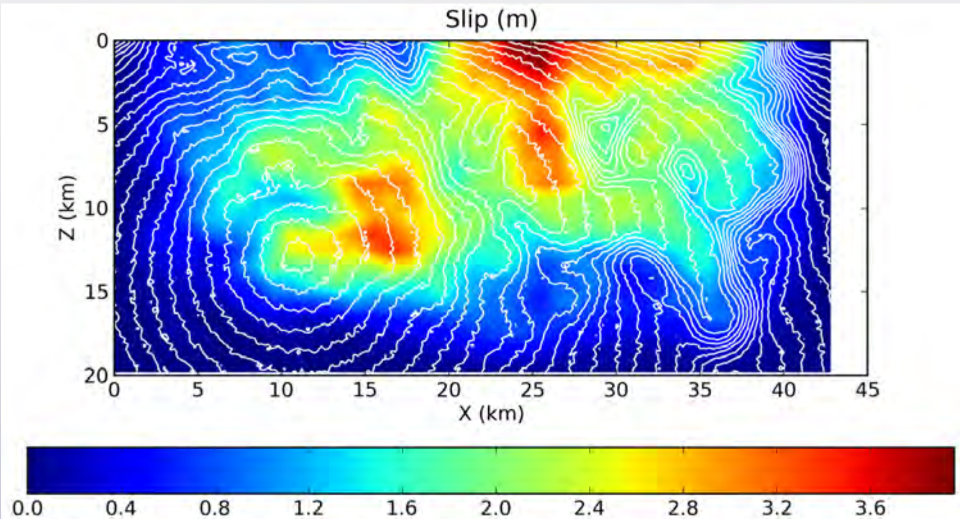
Spontaneous rupture simulations

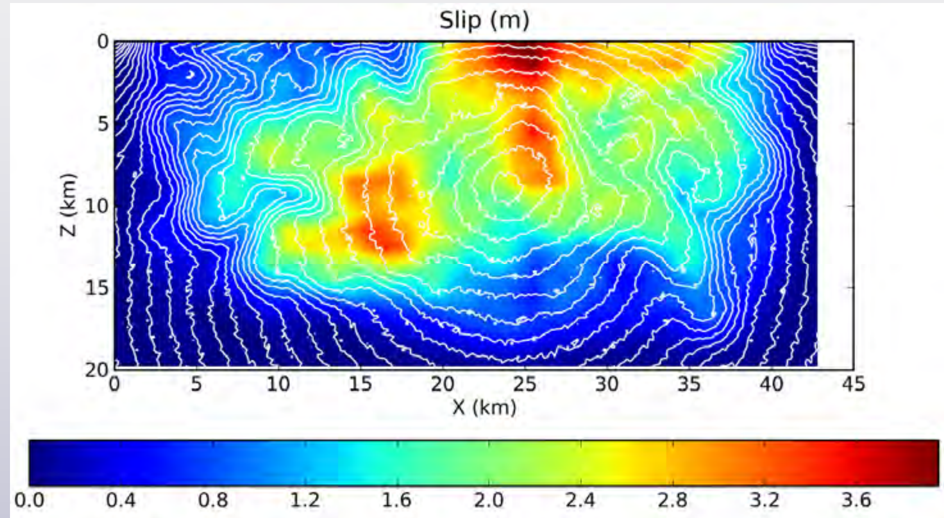
- Finite difference method is used to simulate the dynamic rupture process based on mechanical models of friction and stress drop on the fault

(Dalguer, L. A., and S. M. Day, 2007. *Staggered-grid split-node method for spontaneous rupture simulation*, J. Geophys. Res. 112, B02302, doi 10.1029/2006JB004467.)

Pseudo-dynamic rupture models

Two scenarios with identical final slip, but different hypocenter

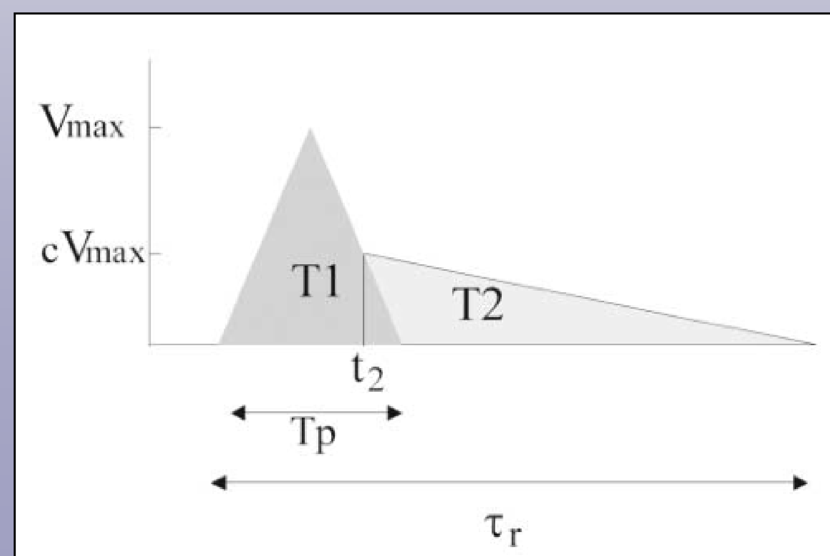




- Generation of a slip distribution as a spatially random field, spatial variability and scaling consistent with previous earthquakes
- Static stress drop associated with slip distribution is computed
- Temporal evolution of slip is estimated through empirical relationships derived from spontaneous rupture models

- 4 parameters describing source-velocity function (SVF)
- on each source node:

- V_{max}: maximum slip velocity
- t_0: rupture time
- T_p: pulse length
- τ_r: rise time



Dynamic Rupture Models

Frictional Parameters and Pre-stress Conditions Design Procedure

Starting Point

Trial Stress Drop : $\otimes|_{Tr}$

→ Trial Slip: S_{Tr}

→ Slip Scenario: S_{Sc}

→ Stress drop and strength excess scenario: $\otimes|_{Sc}$

Ending Point

Static Rupture Simulation FDM (WFCVM)

Slip Scaling with Peak Slip Constraints at the FS

Kinematic Rupture Simulation FDM (WFCVM)

Properties of Our Dynamic Rupture Models

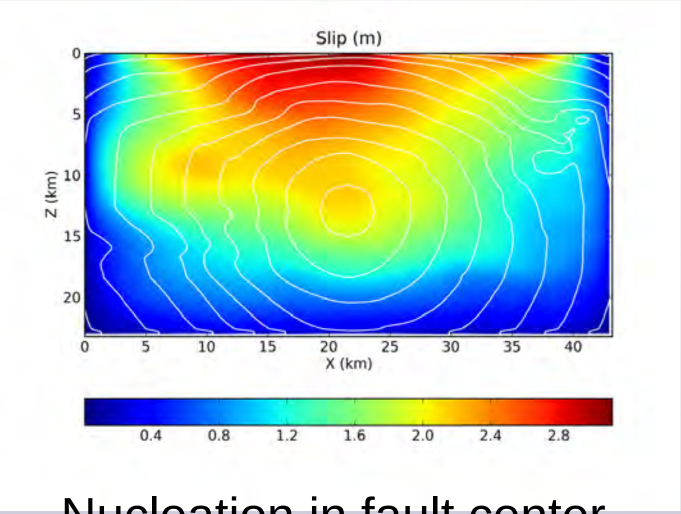
<u>Mechanical</u> (depth dependent material yielding)

<u>Seismological</u> (multi-scale seismic complexity)

<u>Geological</u> (match expected peak slip at the free surface)

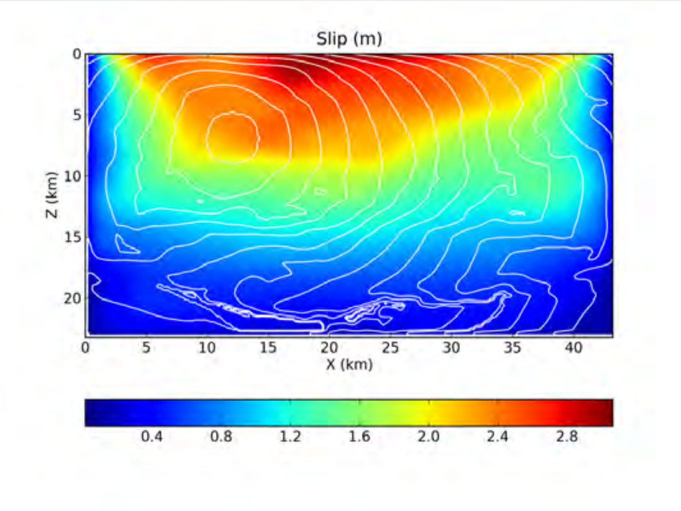
Dynamic Rupture Models

VK3b



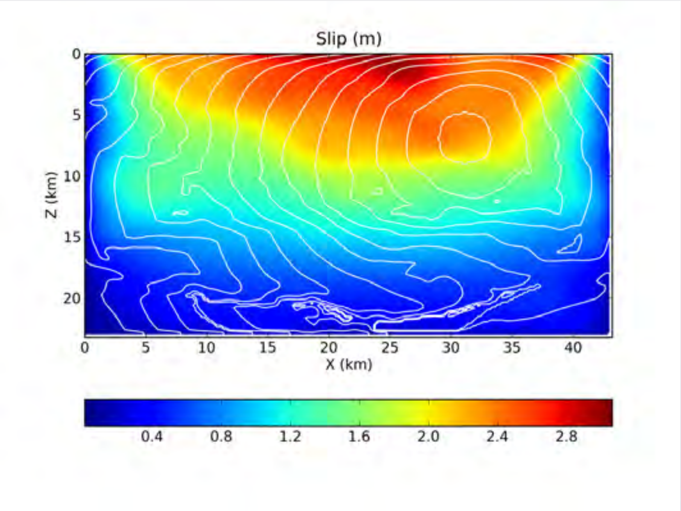
Nucleation in fault center, rupture towards north and south

VK5b



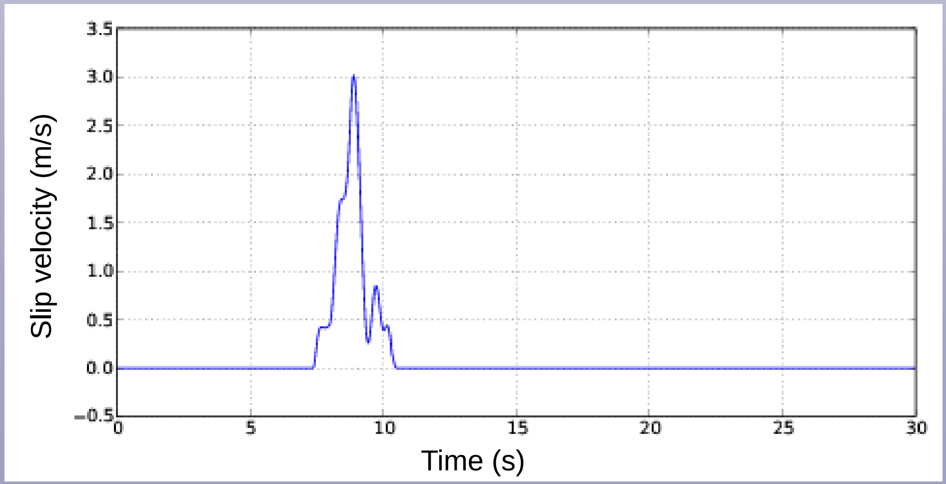
Nucleation in northern part, rupture towards the south

VK5d



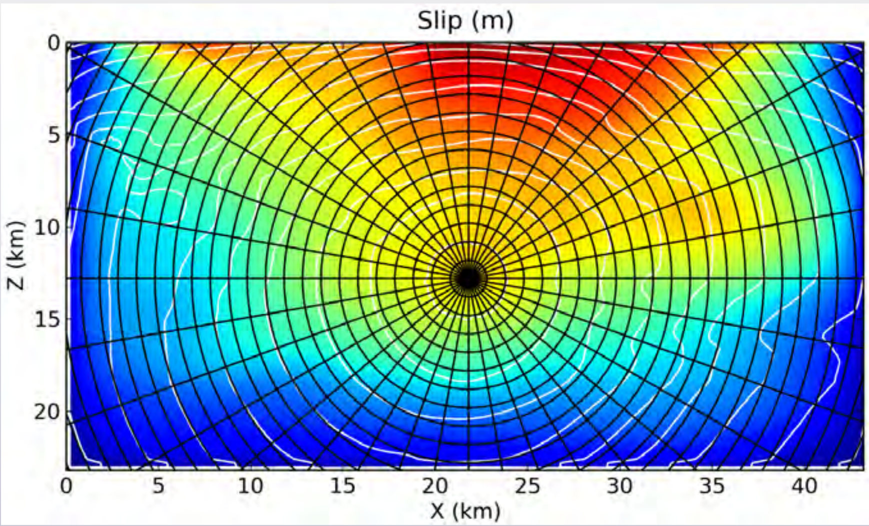
Nucleation in southern part, rupture towards the north

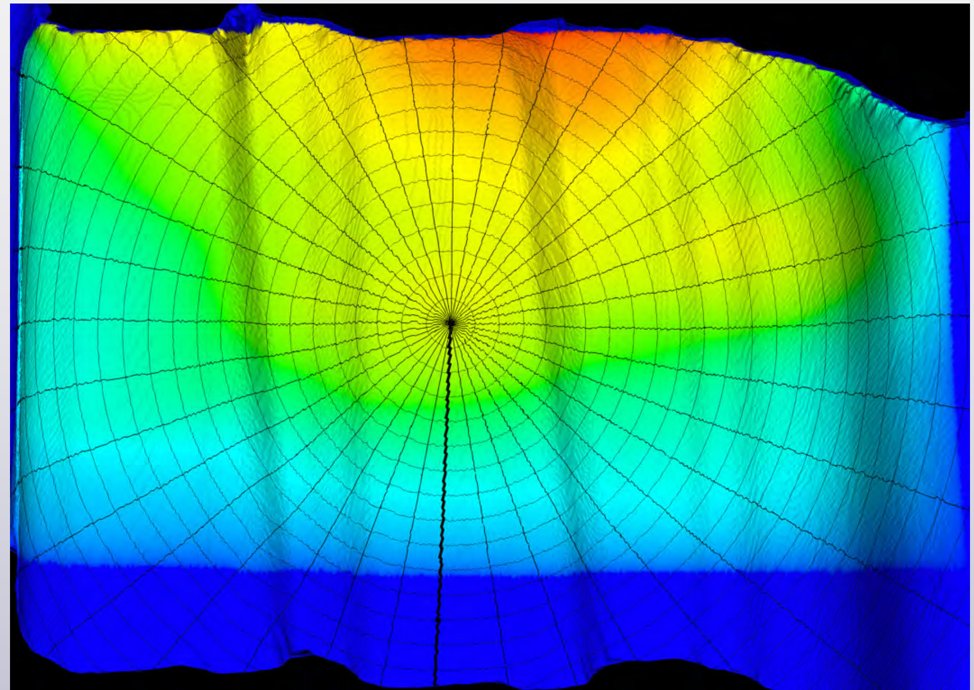
Sample source-velocity-function



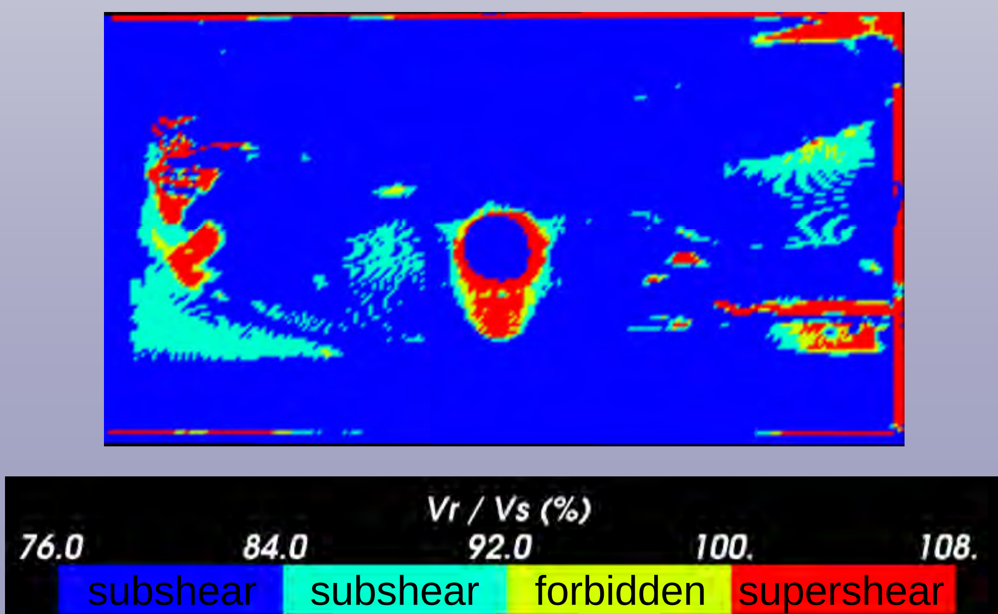
Projecting the Planar Rupture Models onto Irregular WF

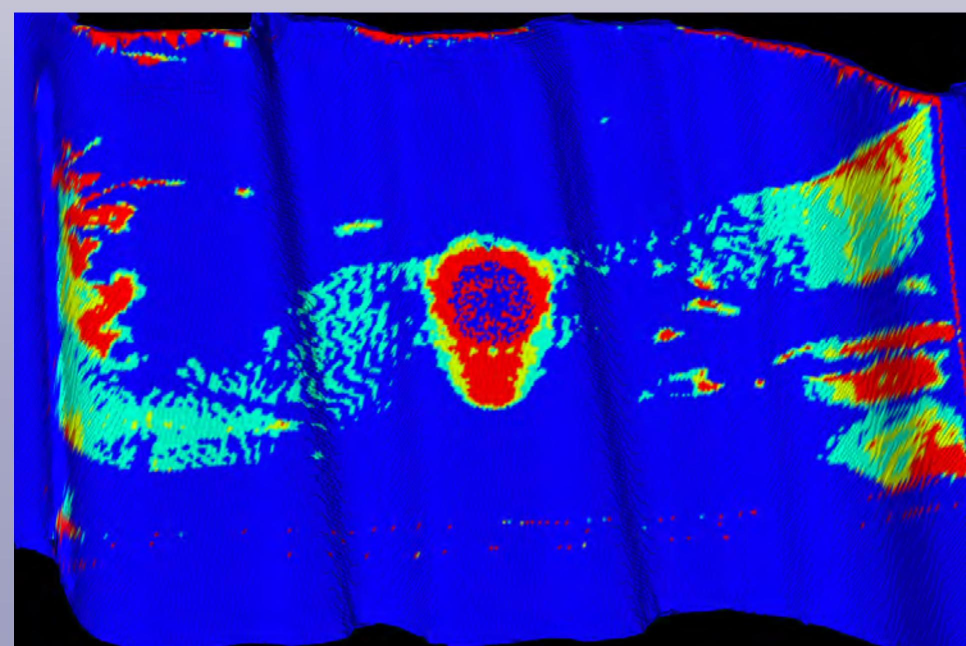
Polar grid with origin in hypocenter on planar fault





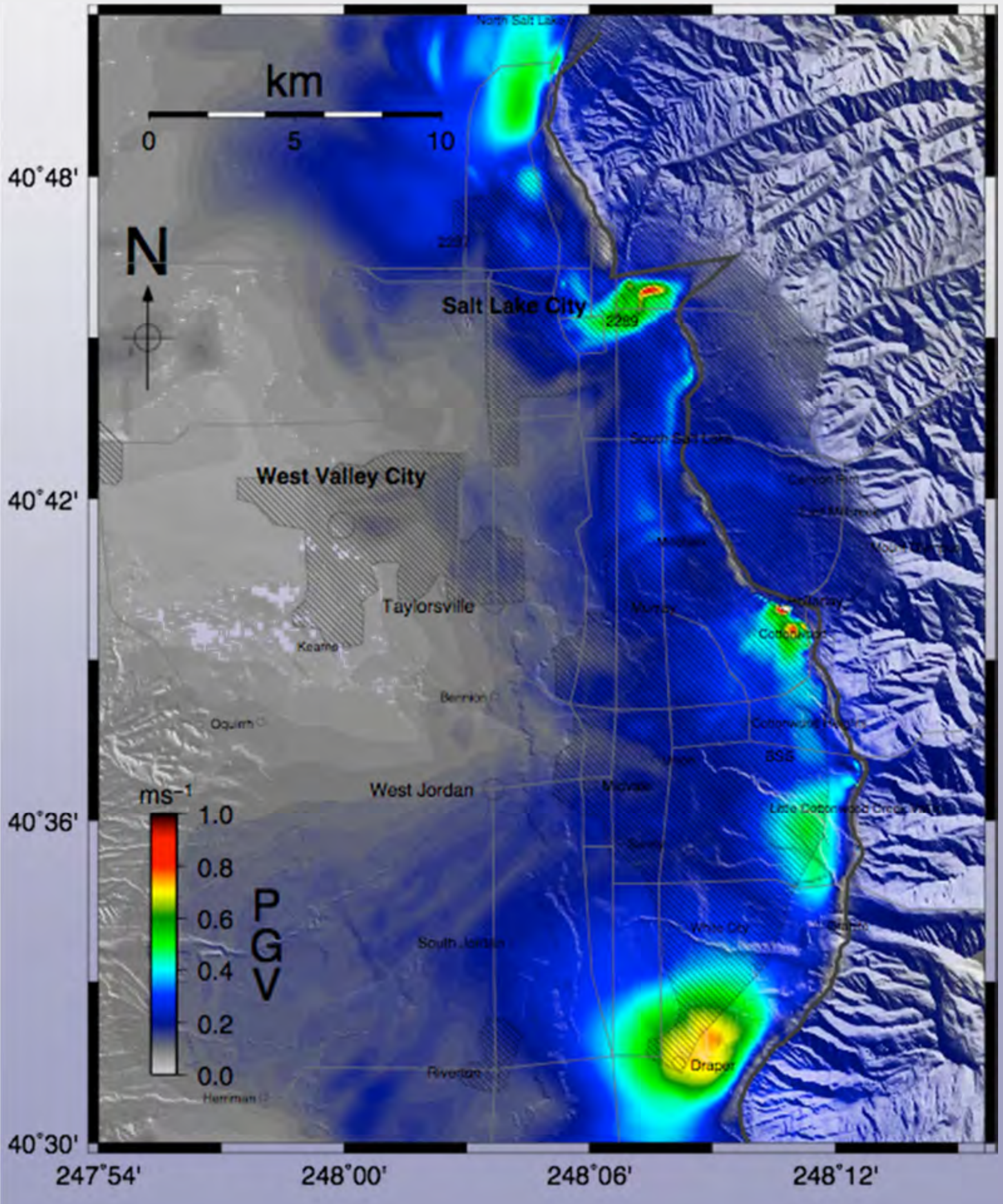
Rupture velocity as fraction of V_s



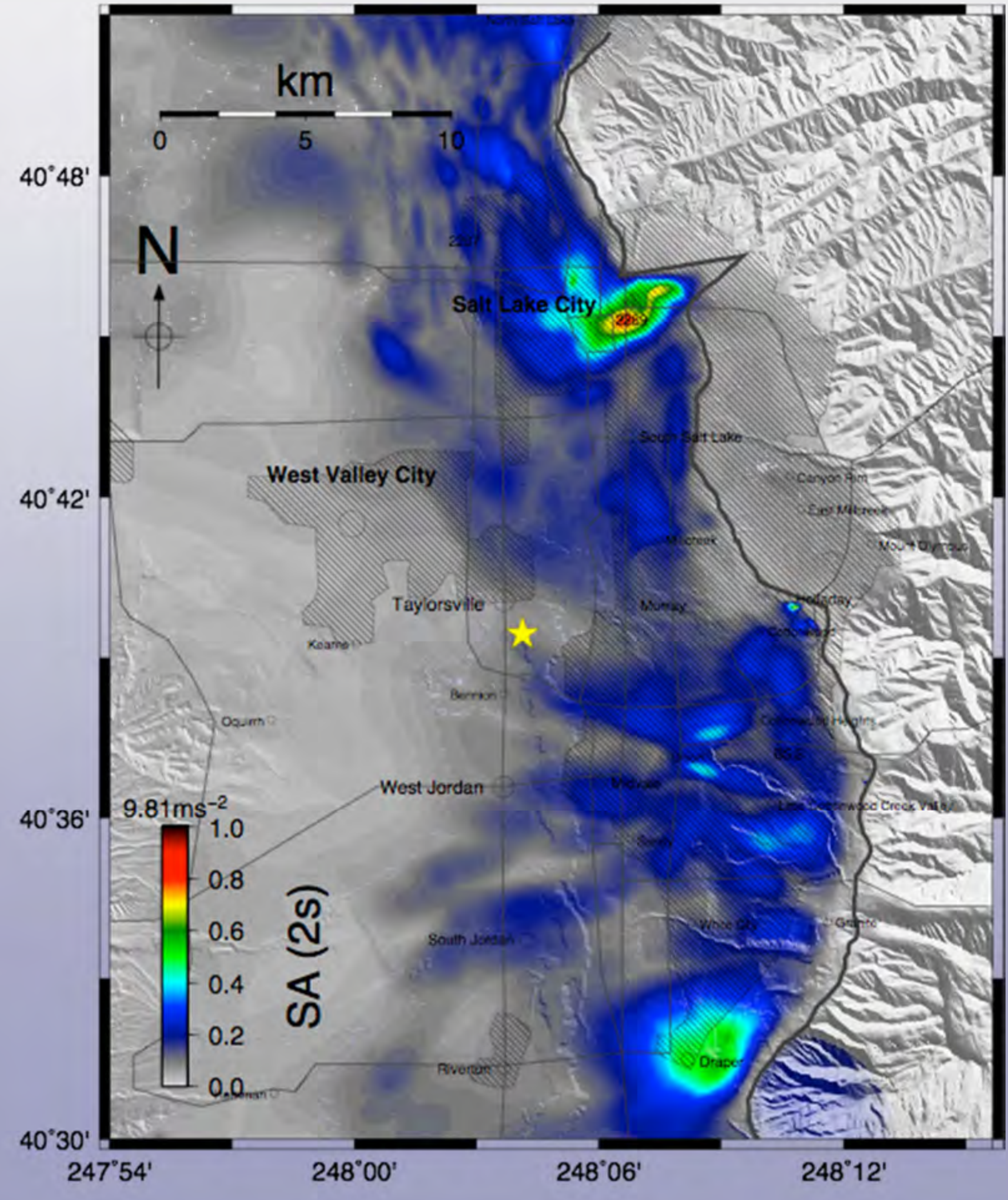


Results - Dynamic Scenario VK3b

Horizontal peak ground velocity



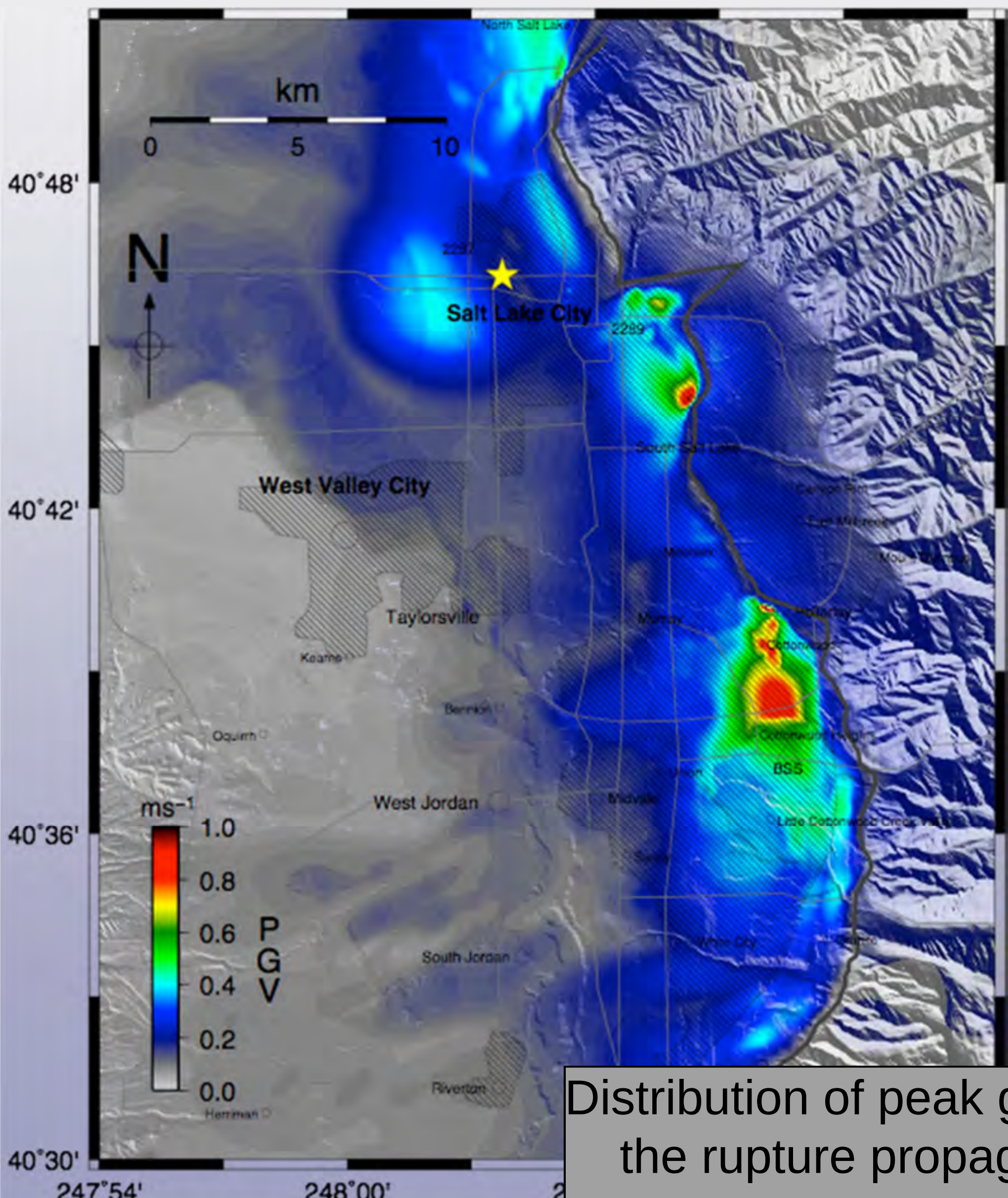
Horizontal peak spectral acceleration at 2 seconds (2s-SAs)



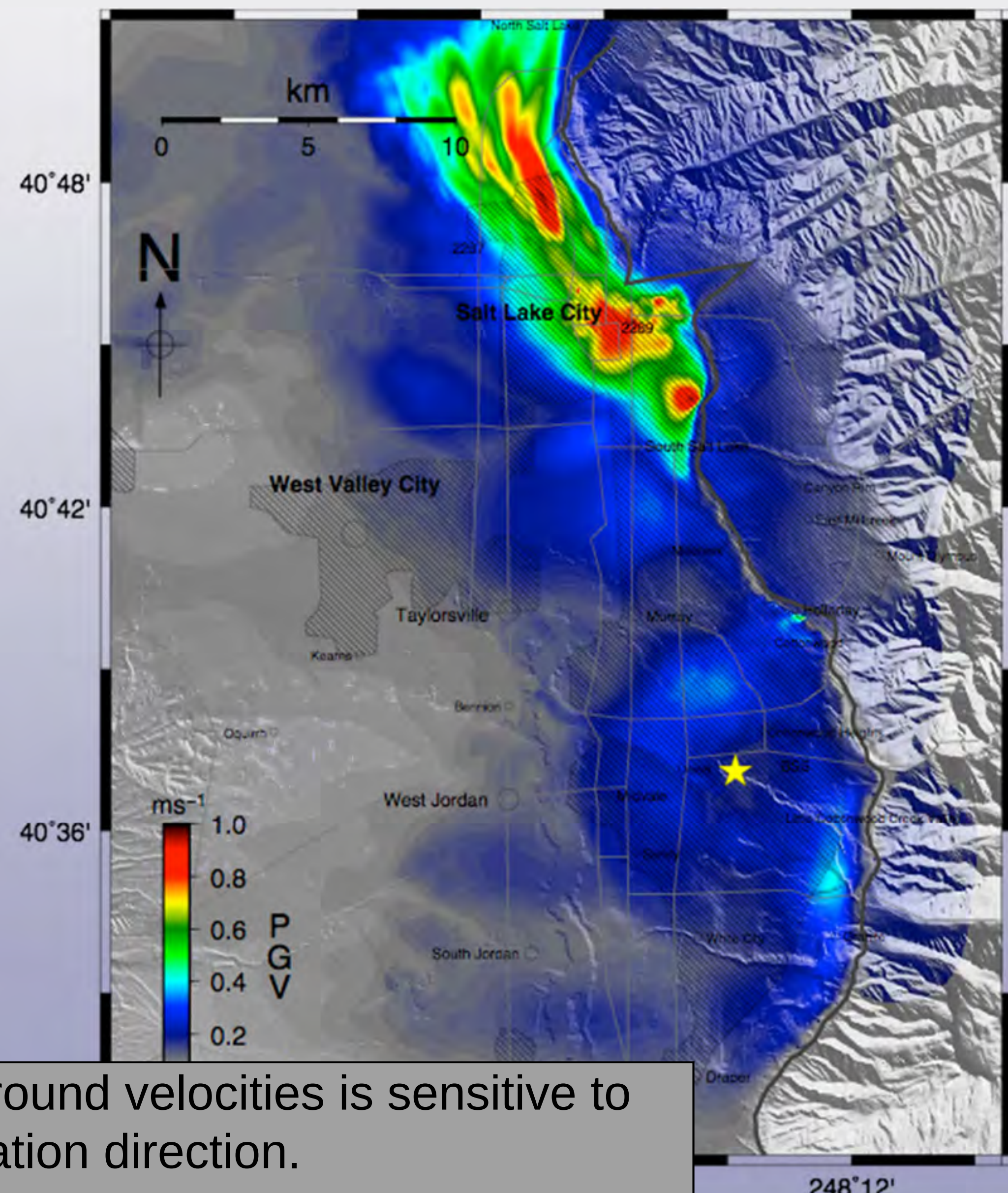
Results - Dynamic Scenarios VK5b / VK5d

Horizontal peak ground velocity

VK5b (rupture from north to south)



VK5d (rupture from north to south)

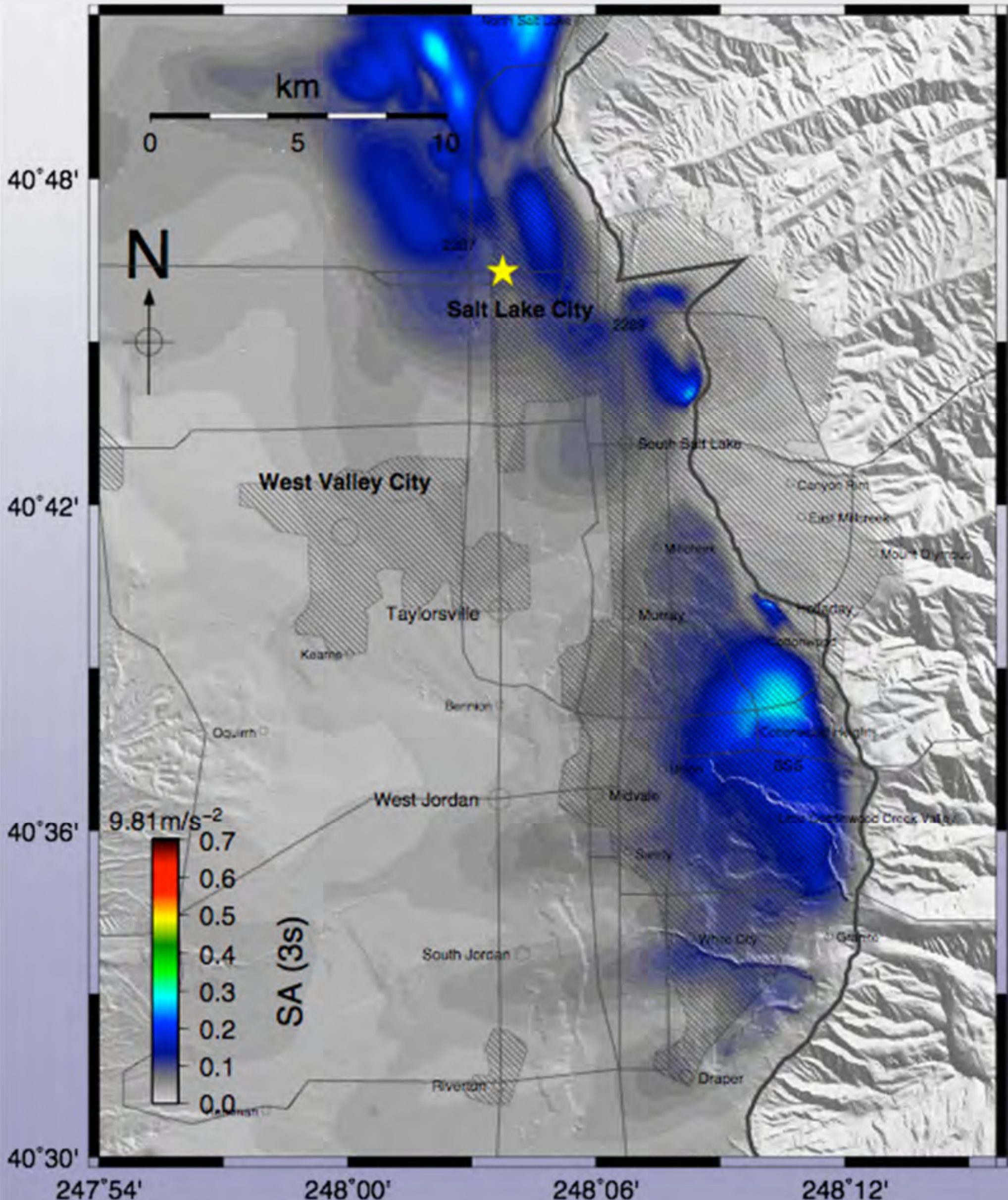


Distribution of peak ground velocities is sensitive to the rupture propagation direction.

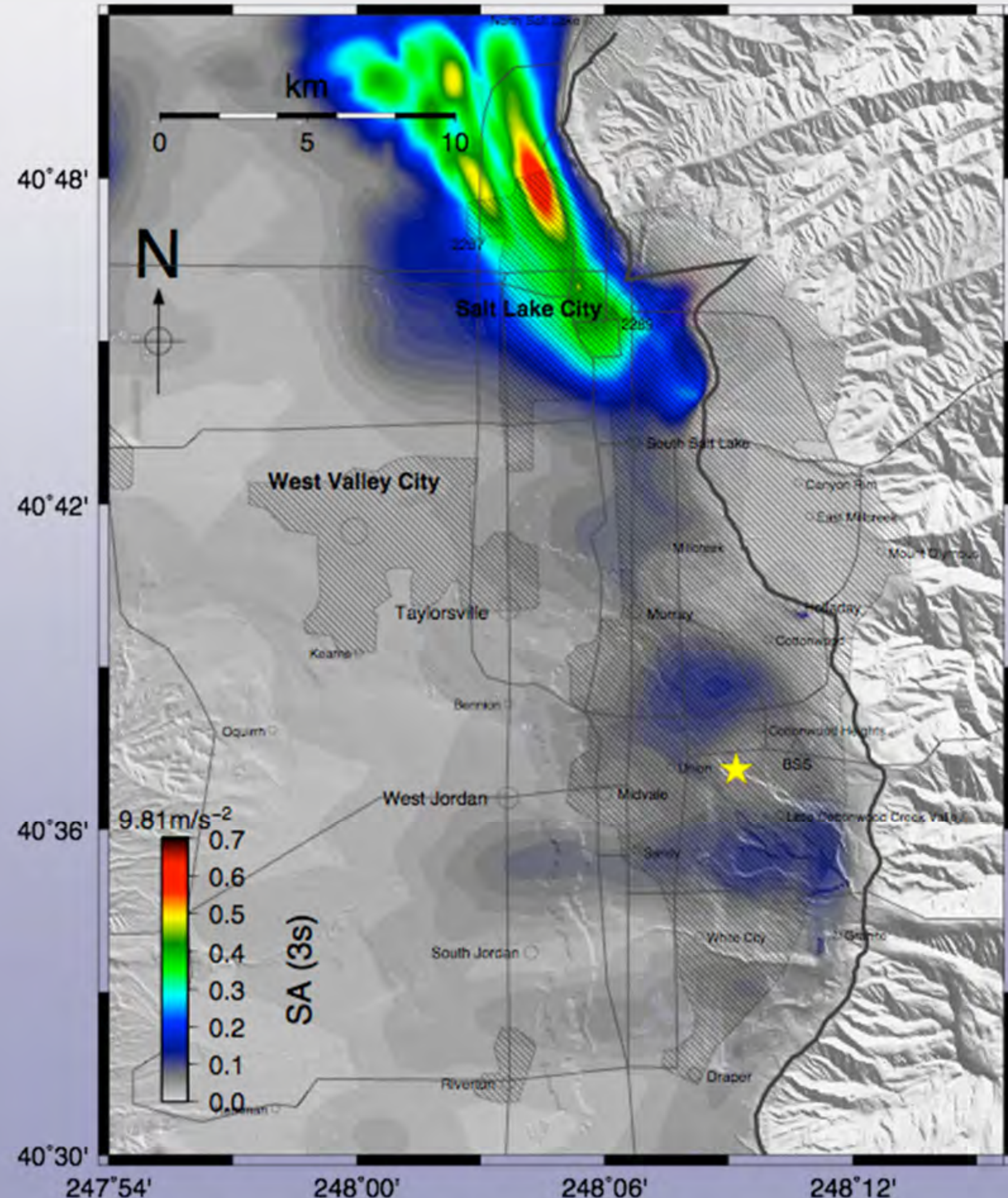
Results - Dynamic Scenarios VK5b / VK5d

3s-SAs (both horizontal components)

VK5b (rupture from north to south)



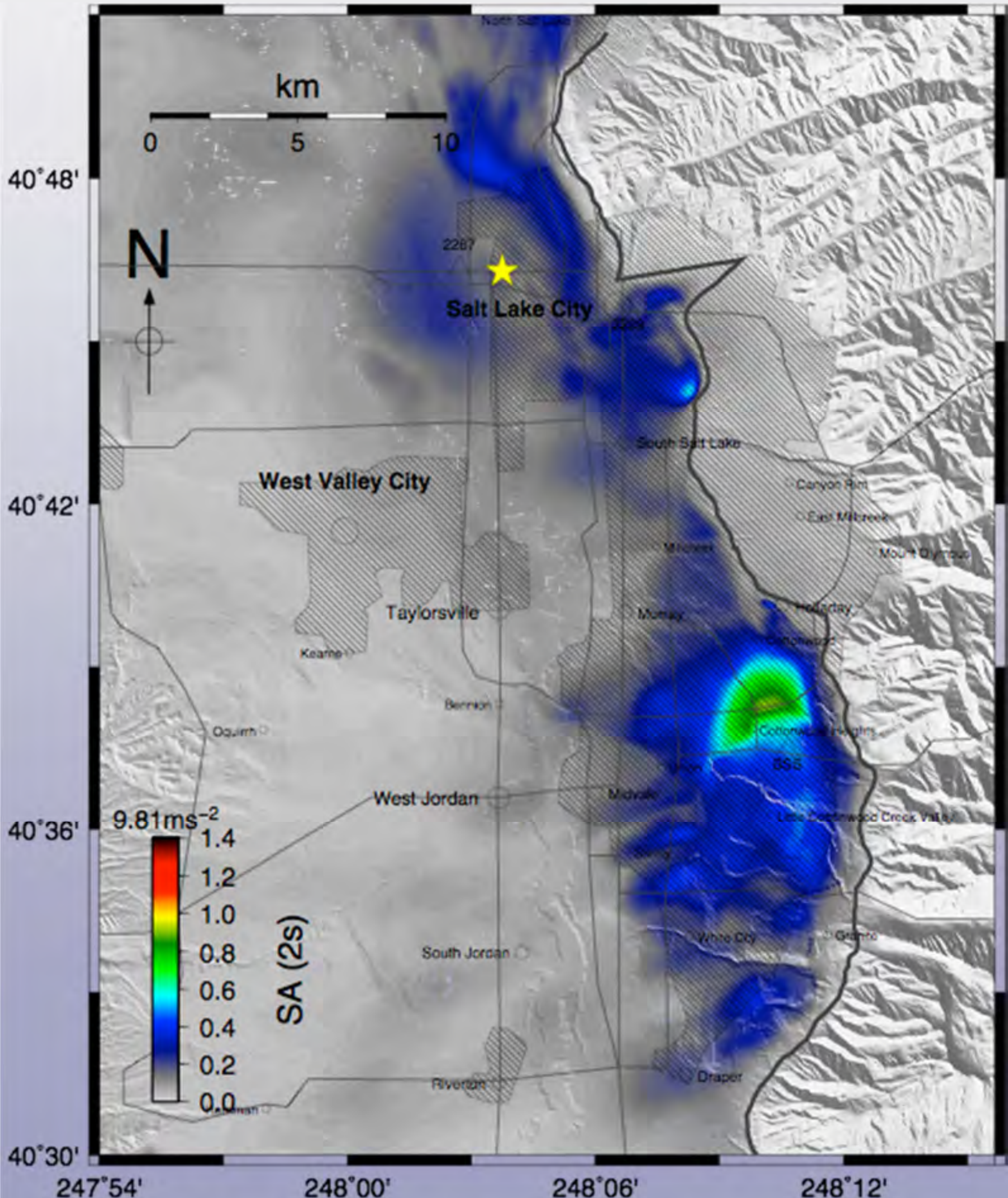
VK5d (rupture from north to south)



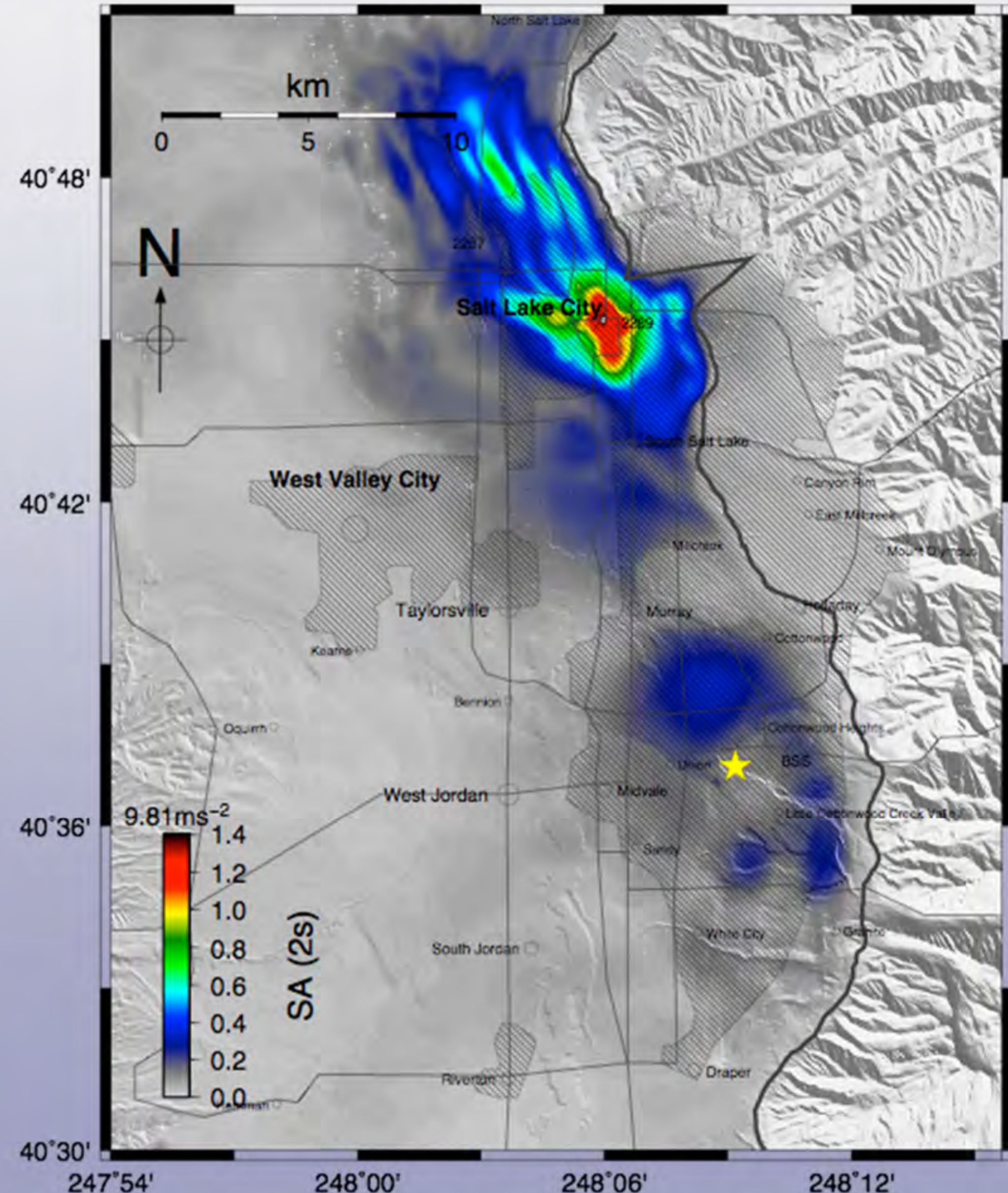
Results - Dynamic Scenarios VK5b / VK5d

2s-SAs (both horizontal components)

VK5b (rupture from north to south)



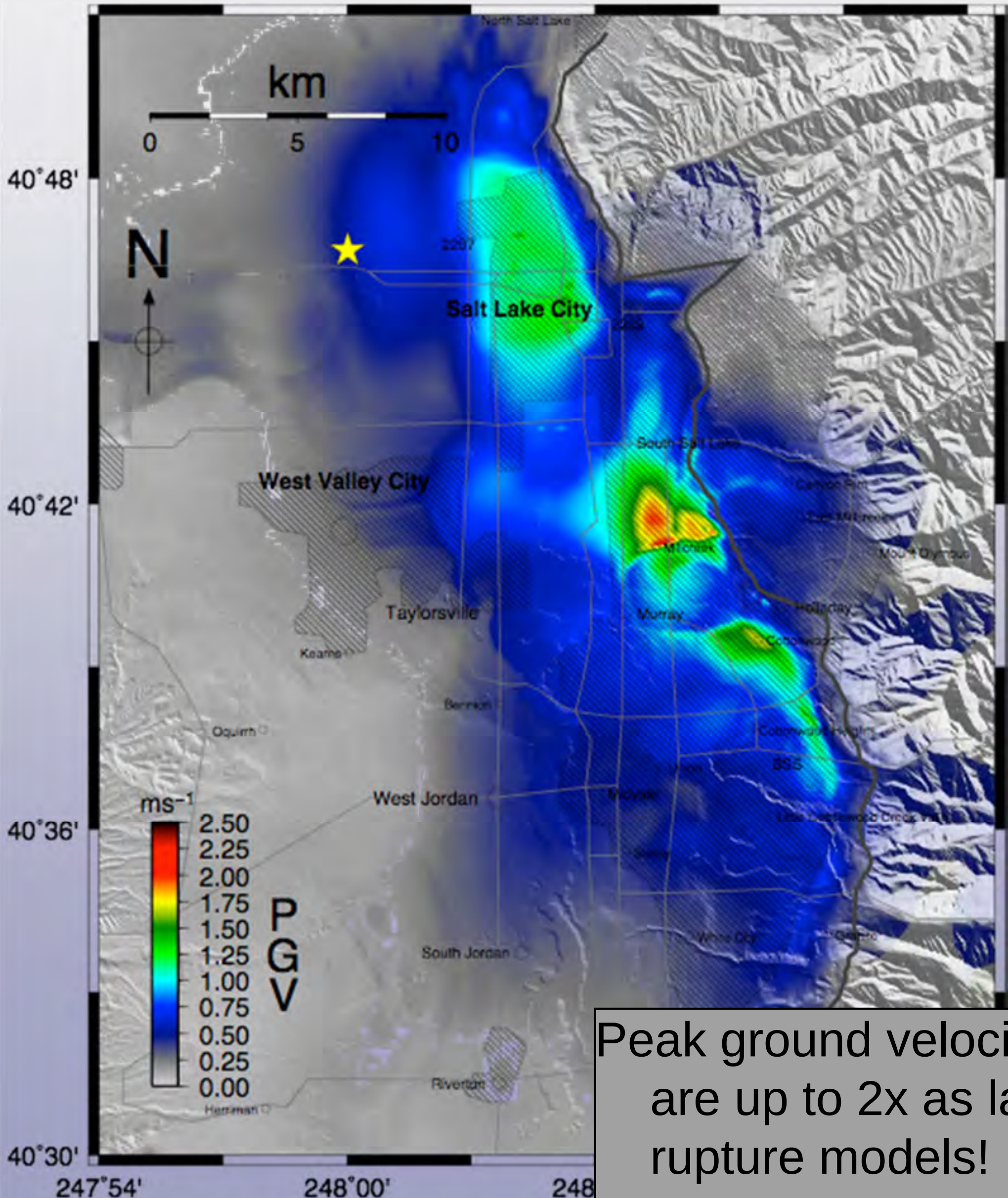
VK5d (rupture from north to south)



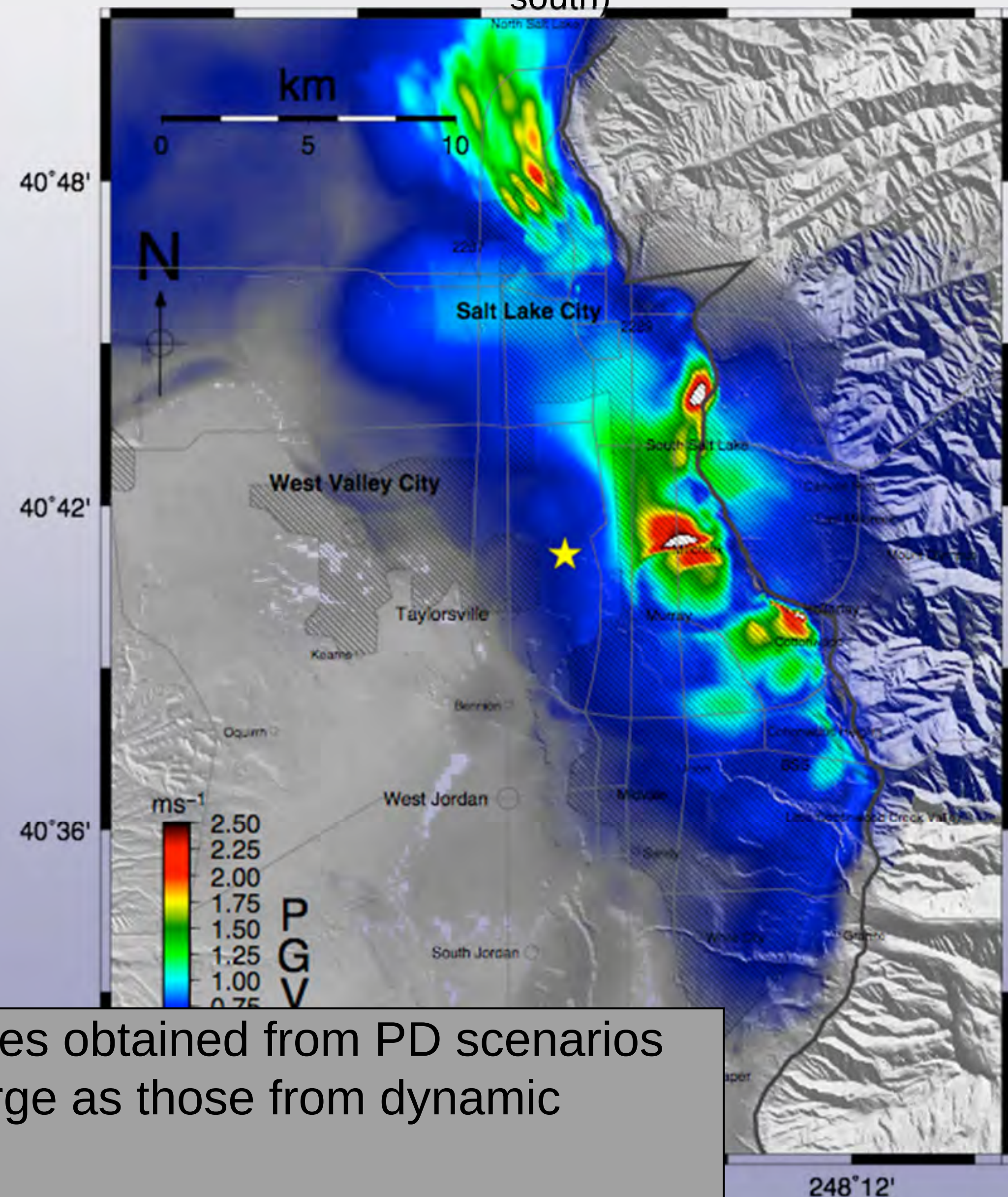
Results - Pseudo-Dynamic Scenarios

Horizontal peak ground velocity

PDS1h0 (rupture from north to south)



PDS1h1 (rupture from center towards north and south)

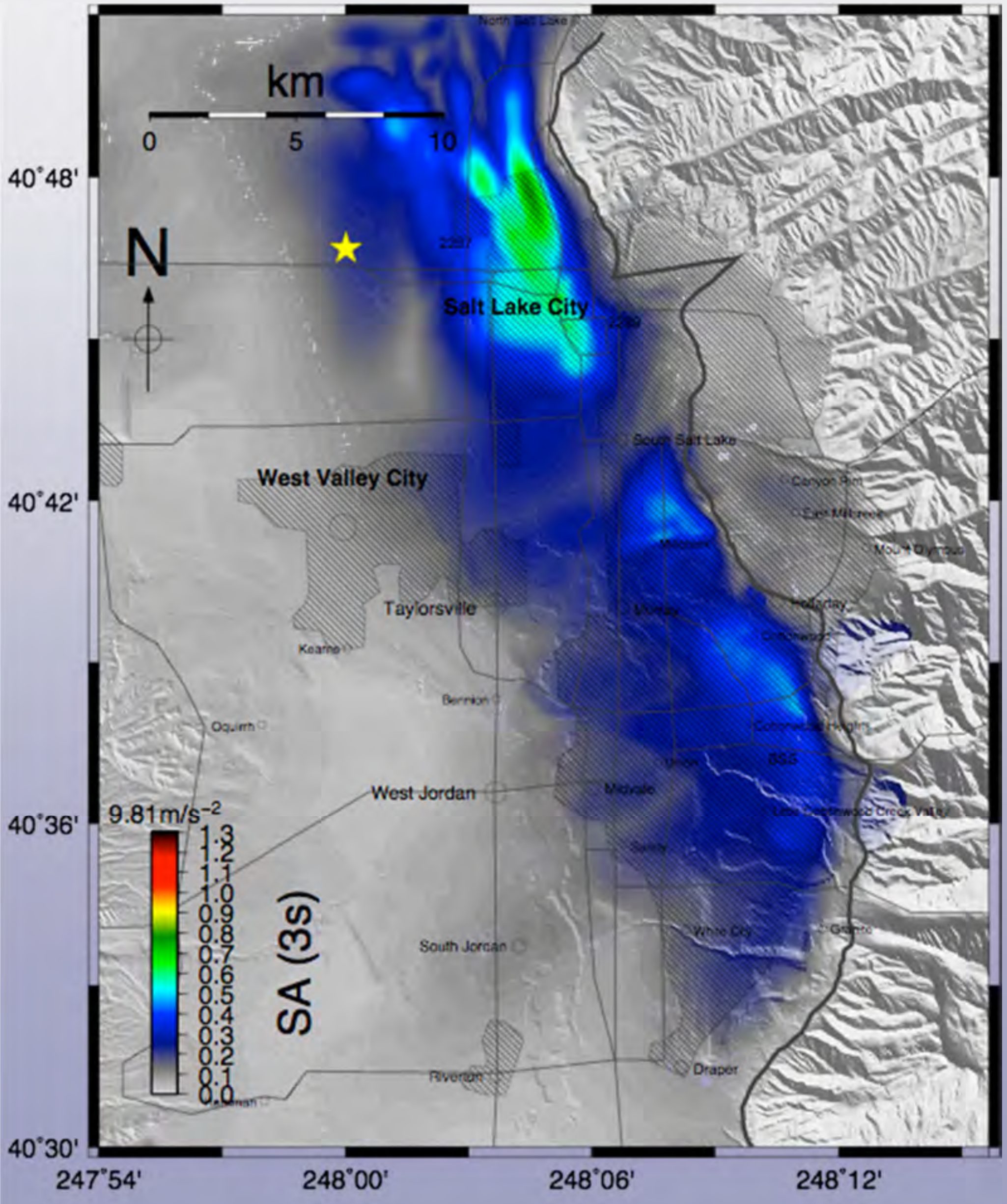


Peak ground velocities obtained from PD scenarios are up to 2x as large as those from dynamic rupture models!

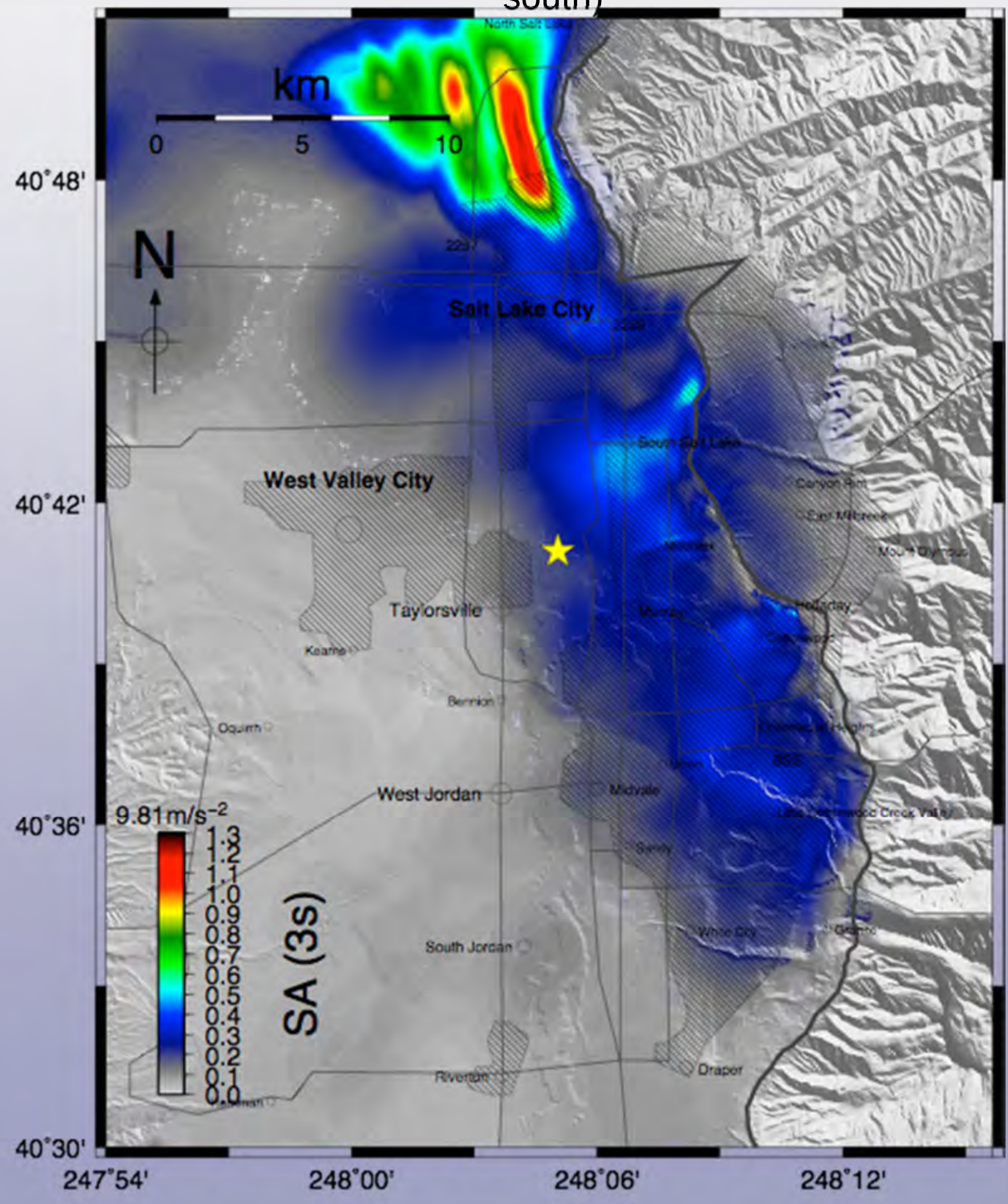
Results - Pseudo-Dynamic Scenarios

3s-SAs (both horizontal components)

PDS1h0 (rupture from north to south)



PDS1h1 (rupture from center towards north and south)

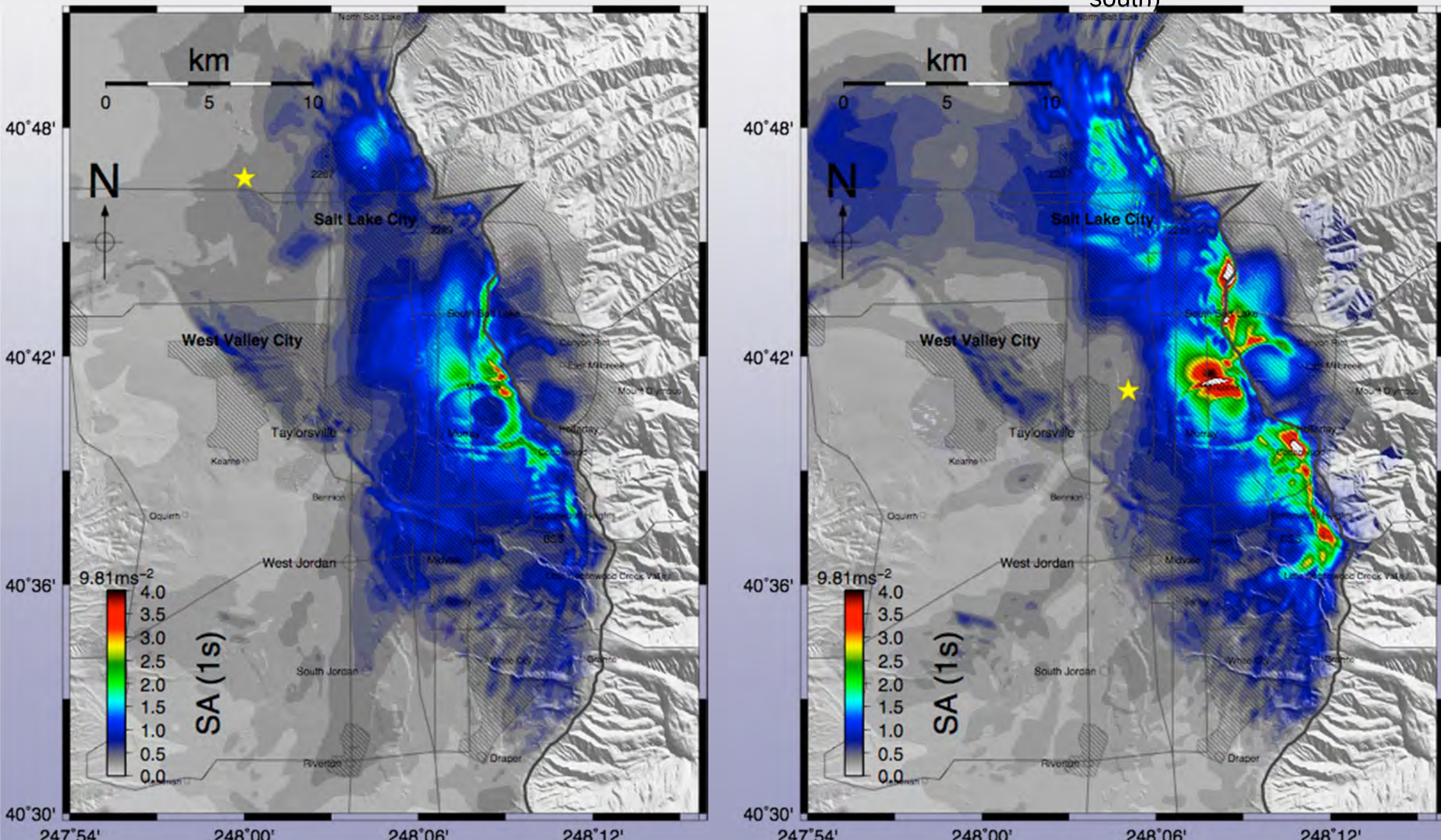


Results - Pseudo-Dynamic Scenarios

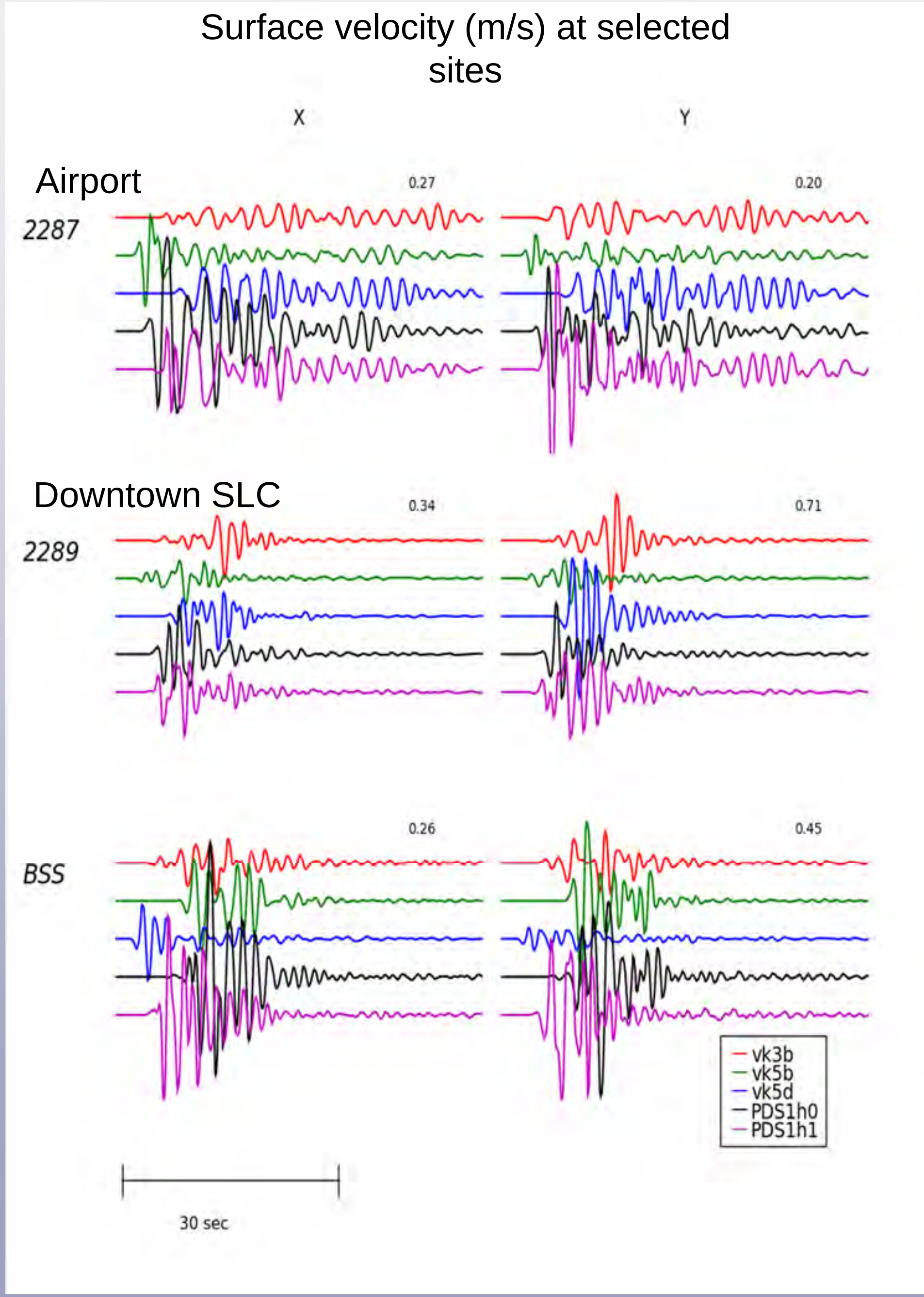
1s-SAs (both horizontal components)

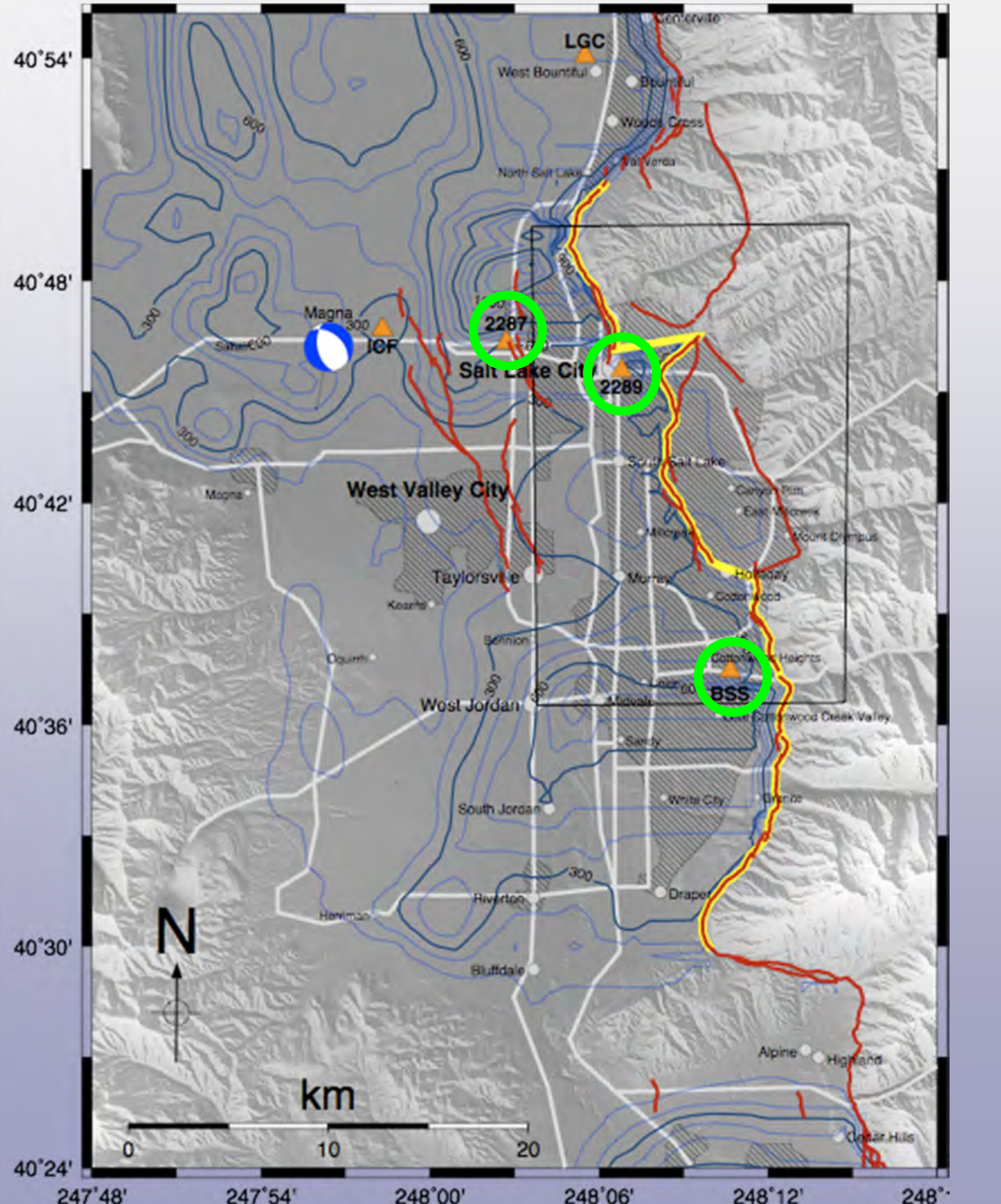
PDS1h0 (rupture from north to south)

PDS1h1 (rupture from center towards north and south)



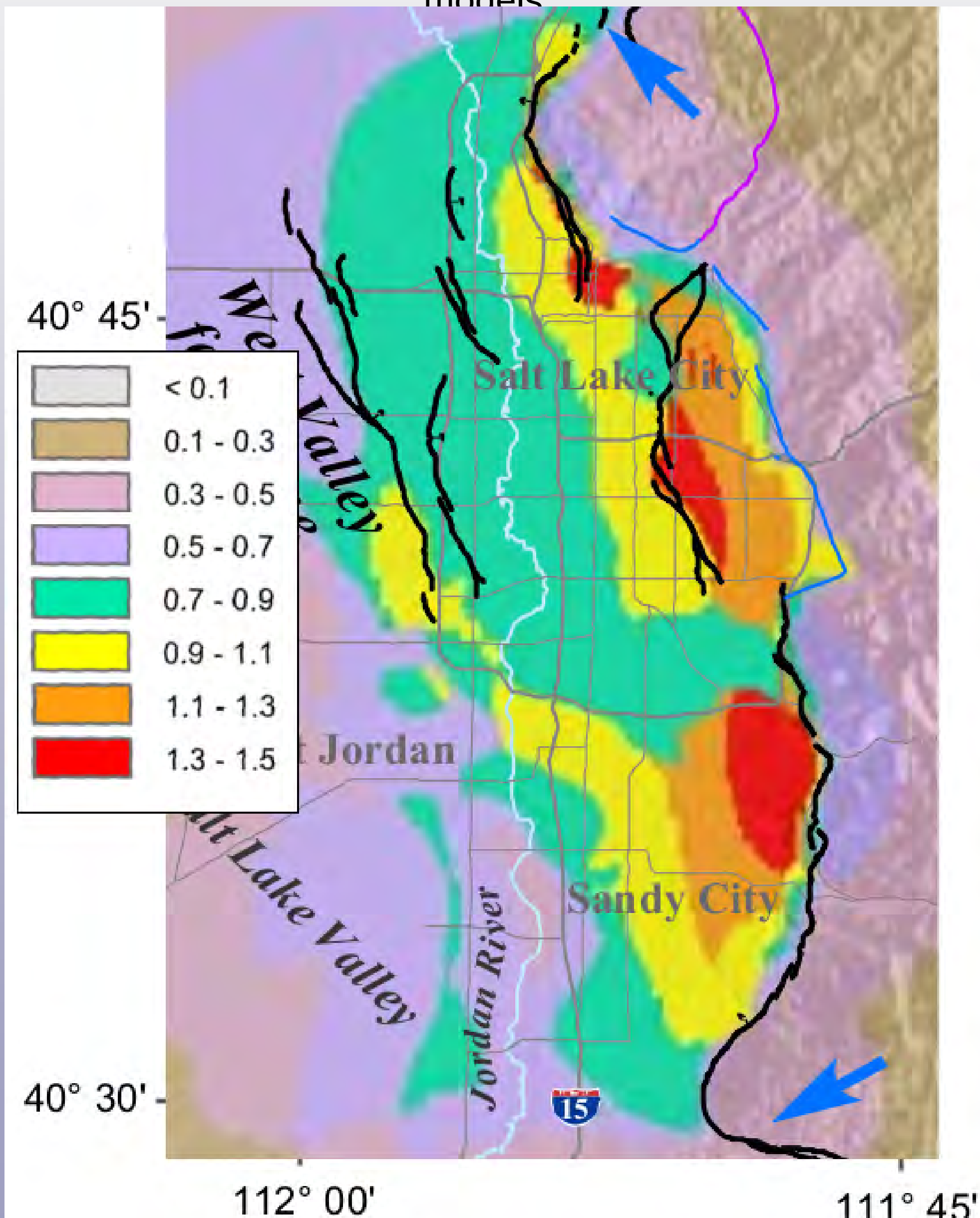
Results - Time Series at Selected Sites



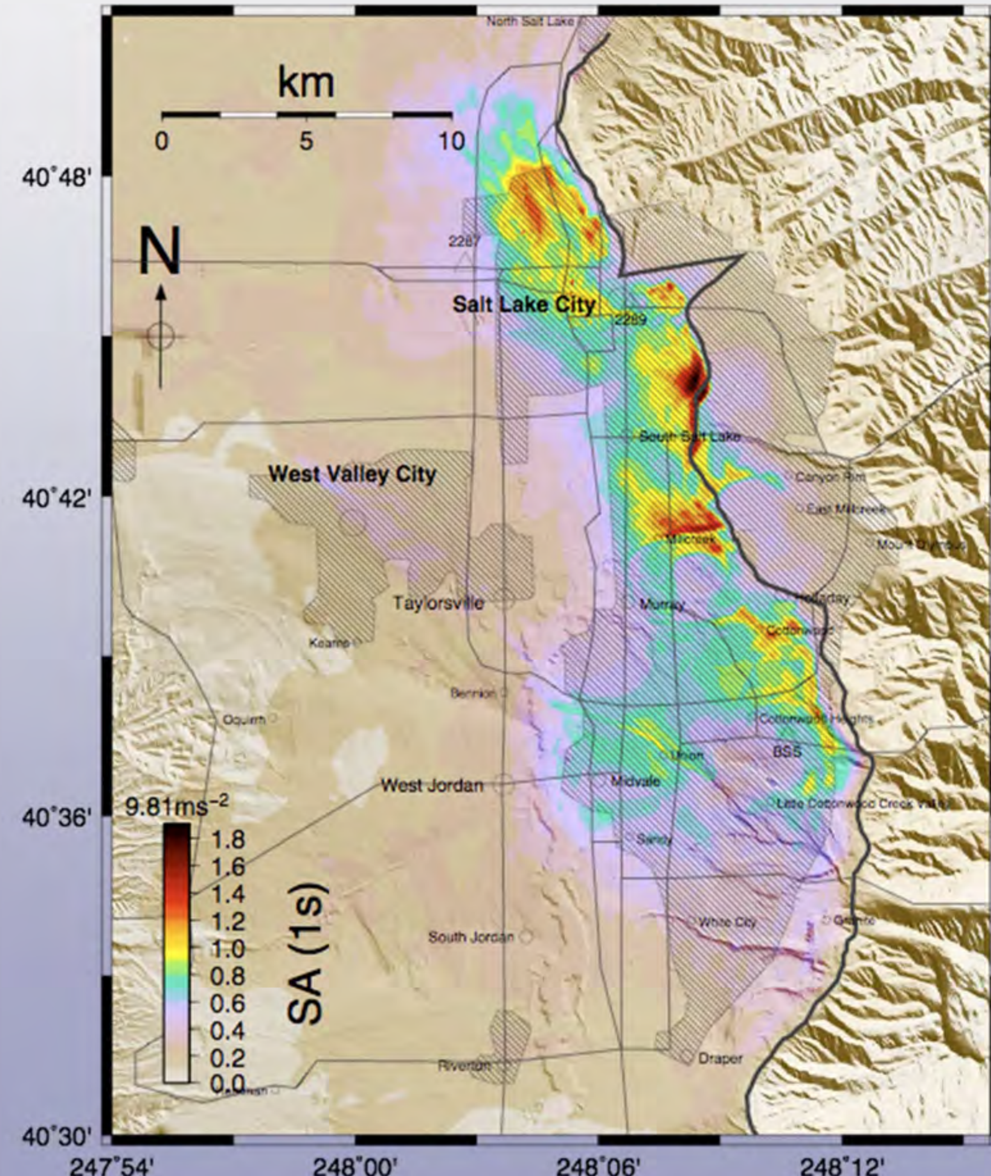


Results - Preliminary Average 1s-SAs

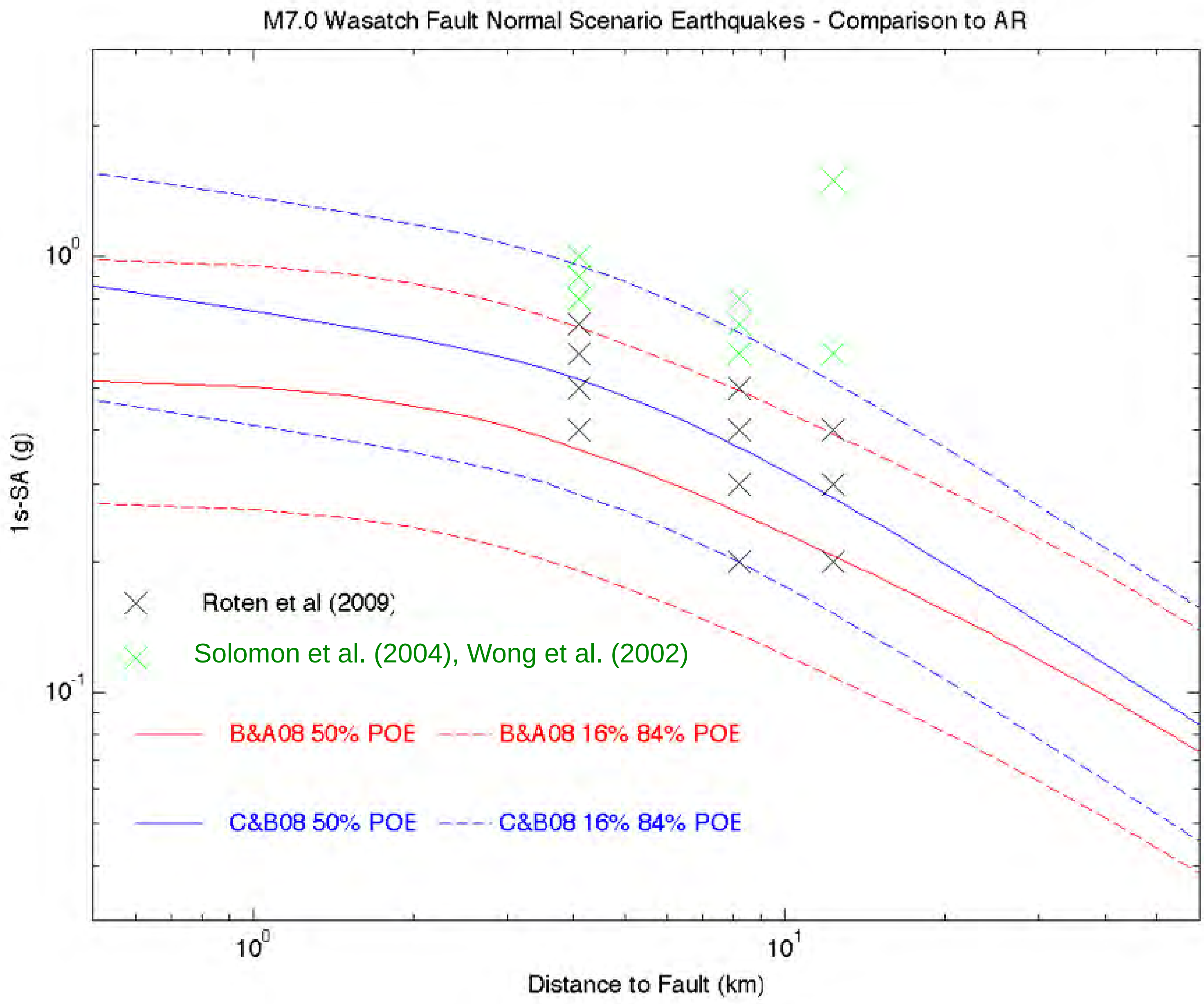
Average 1s-SAs (g) reported by Solomon et al. (2004). Mean of attenuation relationship predictions and the average of 30 simulations with stochastic finite fault models



Average 1s-SAs from dynamic scenario VK5d and both PD scenarios



Comparison of Average 1s-SAs with Empirical Attenuation Models



Near-source broadband ground motions: combining LF-FD synthetics with HF scattering operators

Generation of LF synthetics:

- **3D low-frequency soil structure effects (3D FD simulation)**

  Arbitrary 3D velocity structure
  Arbitrarily complex finite-fault source functions
  Full wavefield

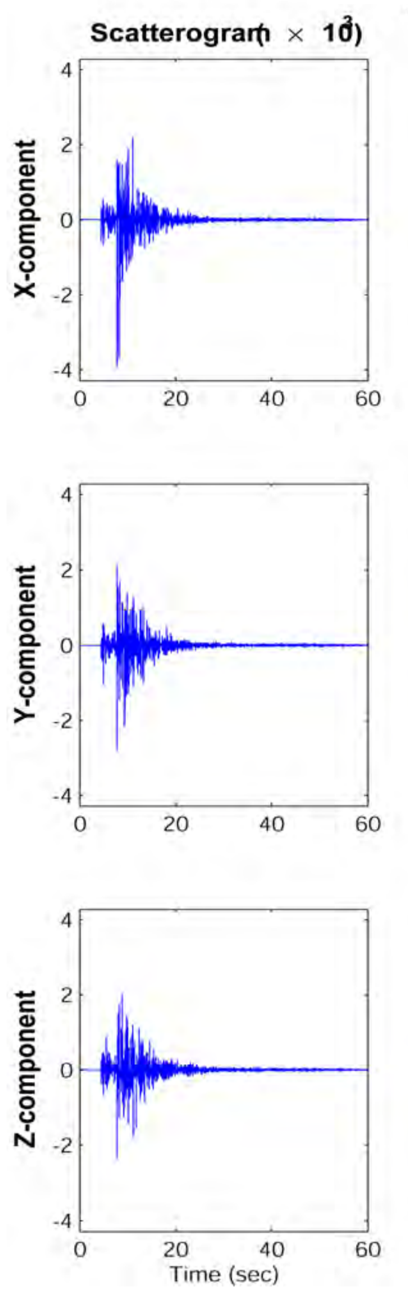
Generation of Scatterograms:

Site-specific scattering operators are calculated (for each component of motion) using the multiple-scattering theory by Zeng et al (1991, 1993) (and their code).

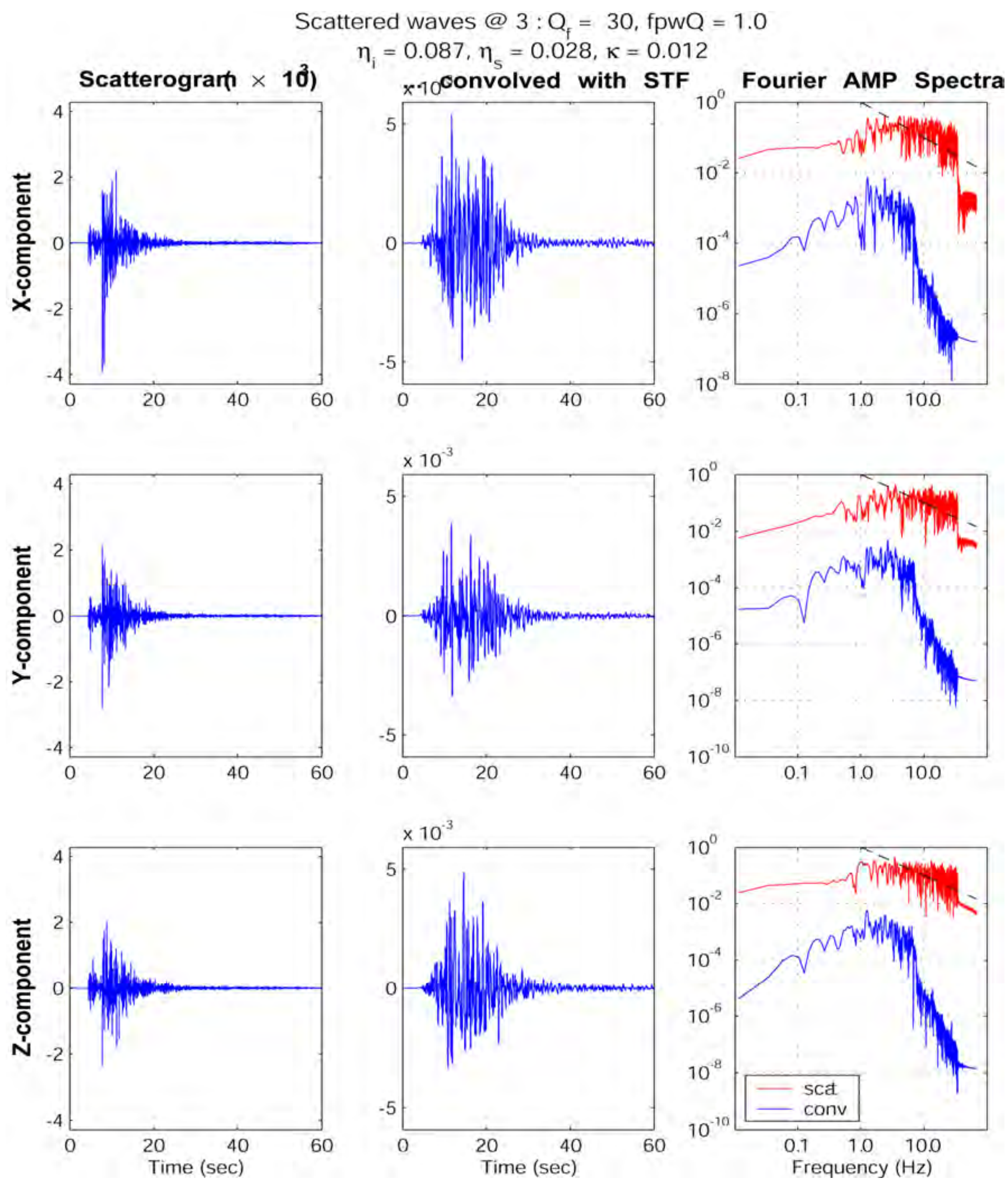
Scattering parameters (scattering and attenuation coefficient, site kappa, intrinsic attenuation) are taken from the literature and are partly based on the site-specific velocity structure.

Assuming scattering operators originate throughout the fault, but starts at the hypocenter

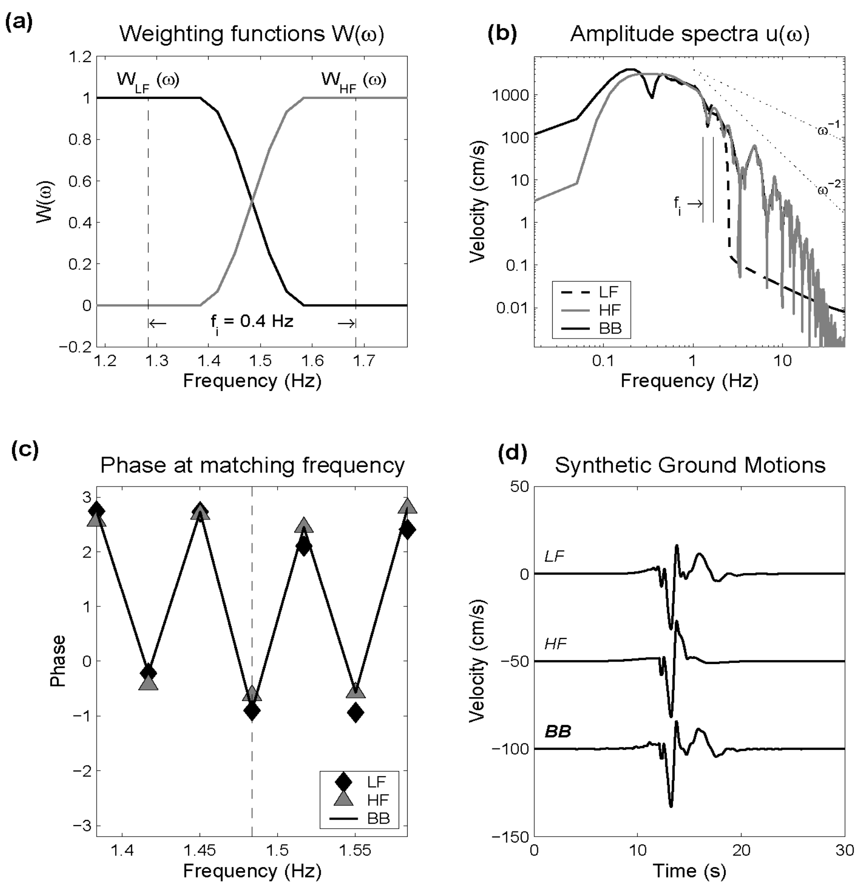
3D FD raytracing to estimate direct P and S travel times.

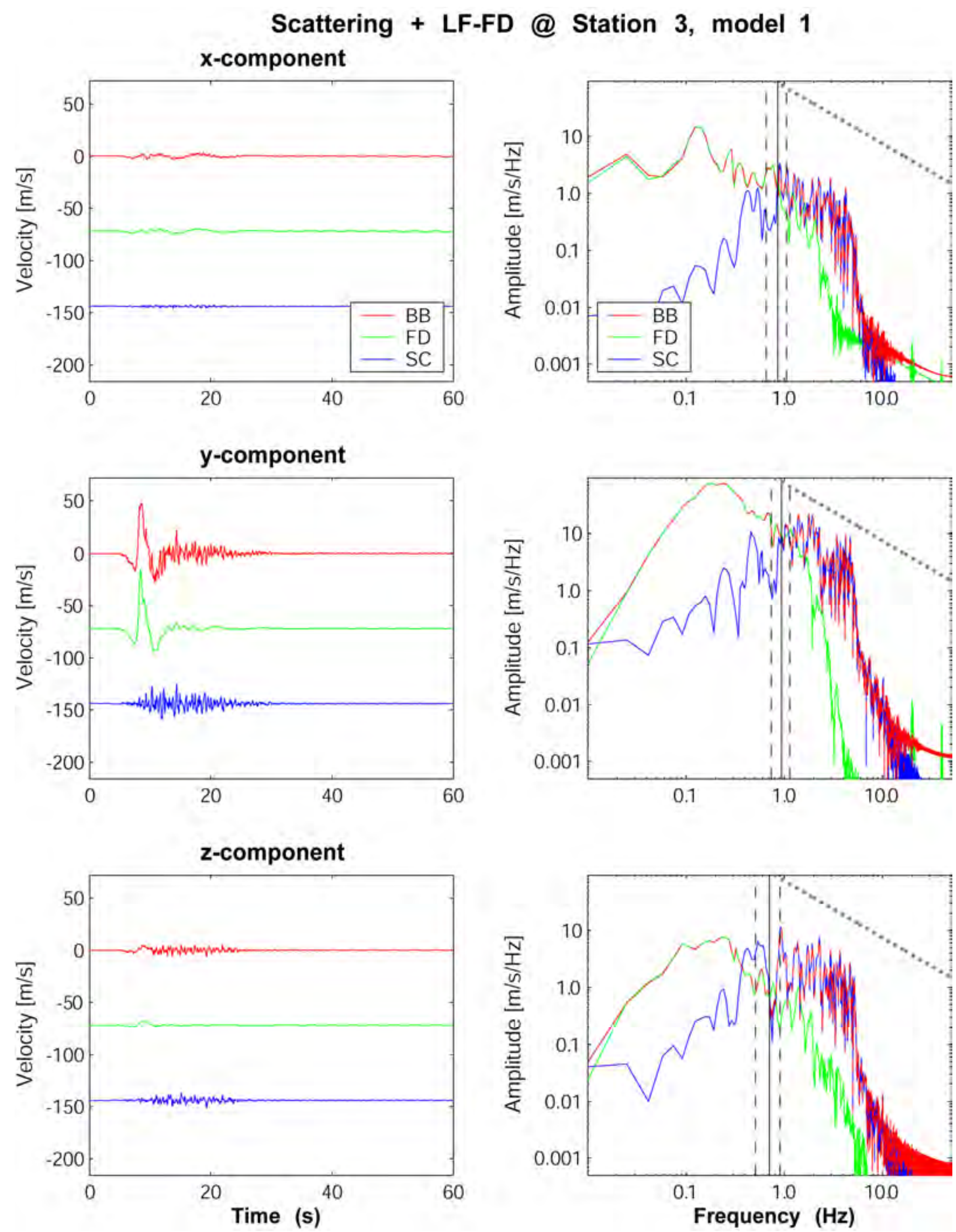


The site-specific scattering Green's functions are convolved with dynamically-consistent source-time functions



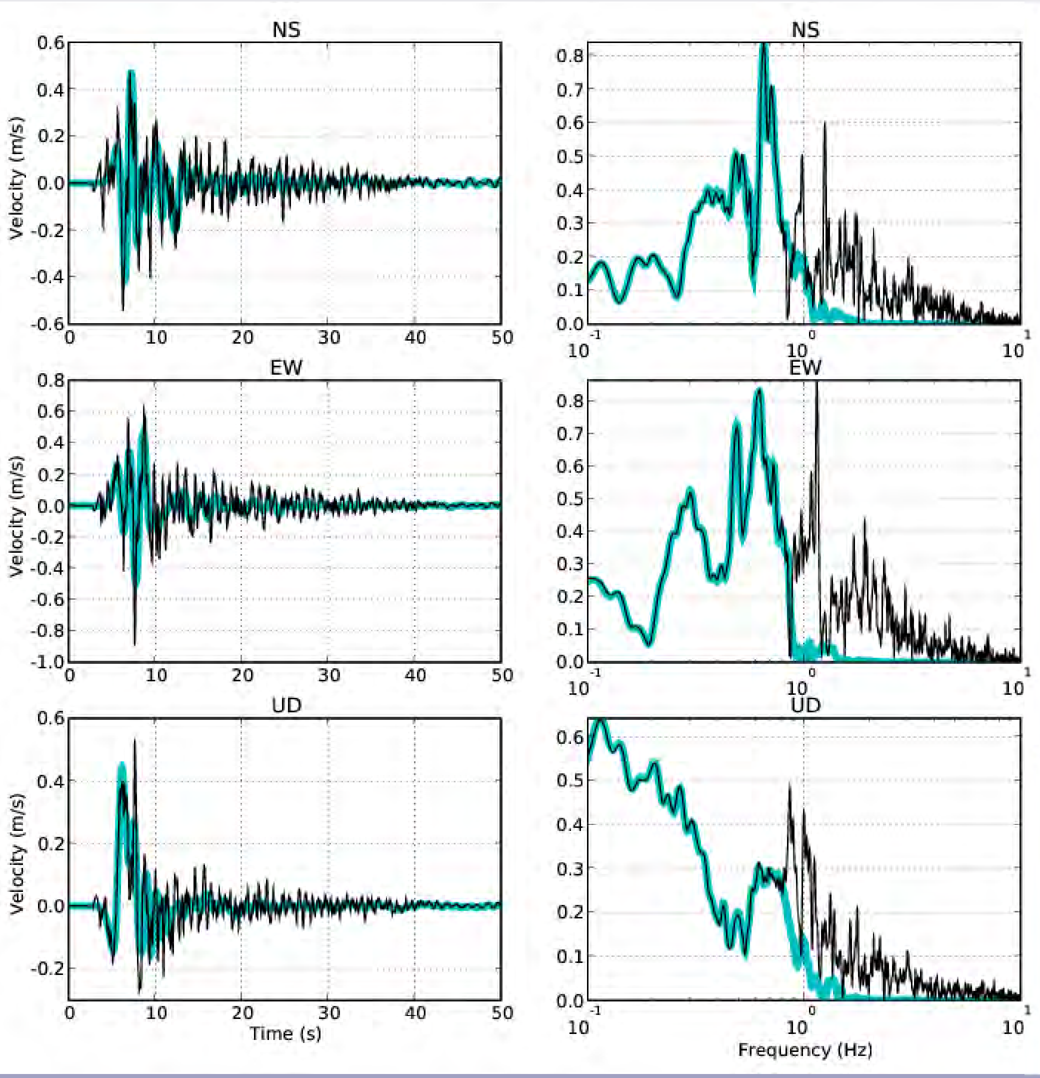
LF and HF synthetics are then combined into broadband seismograms in the frequency domain using a *simultaneous amplitude and phase matching algorithm* (Mai and Beroza, 2003).

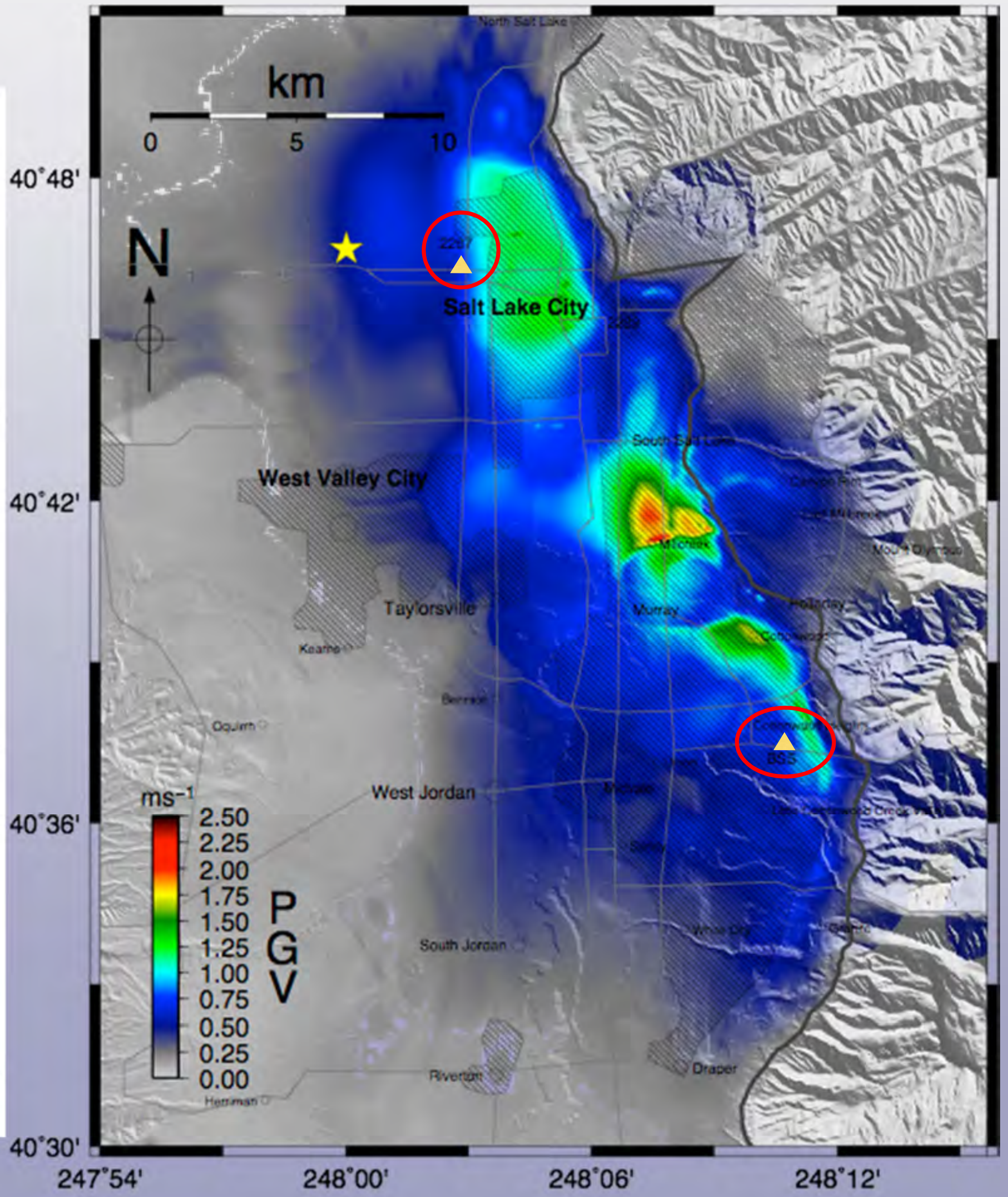




Preliminary BB Time Series

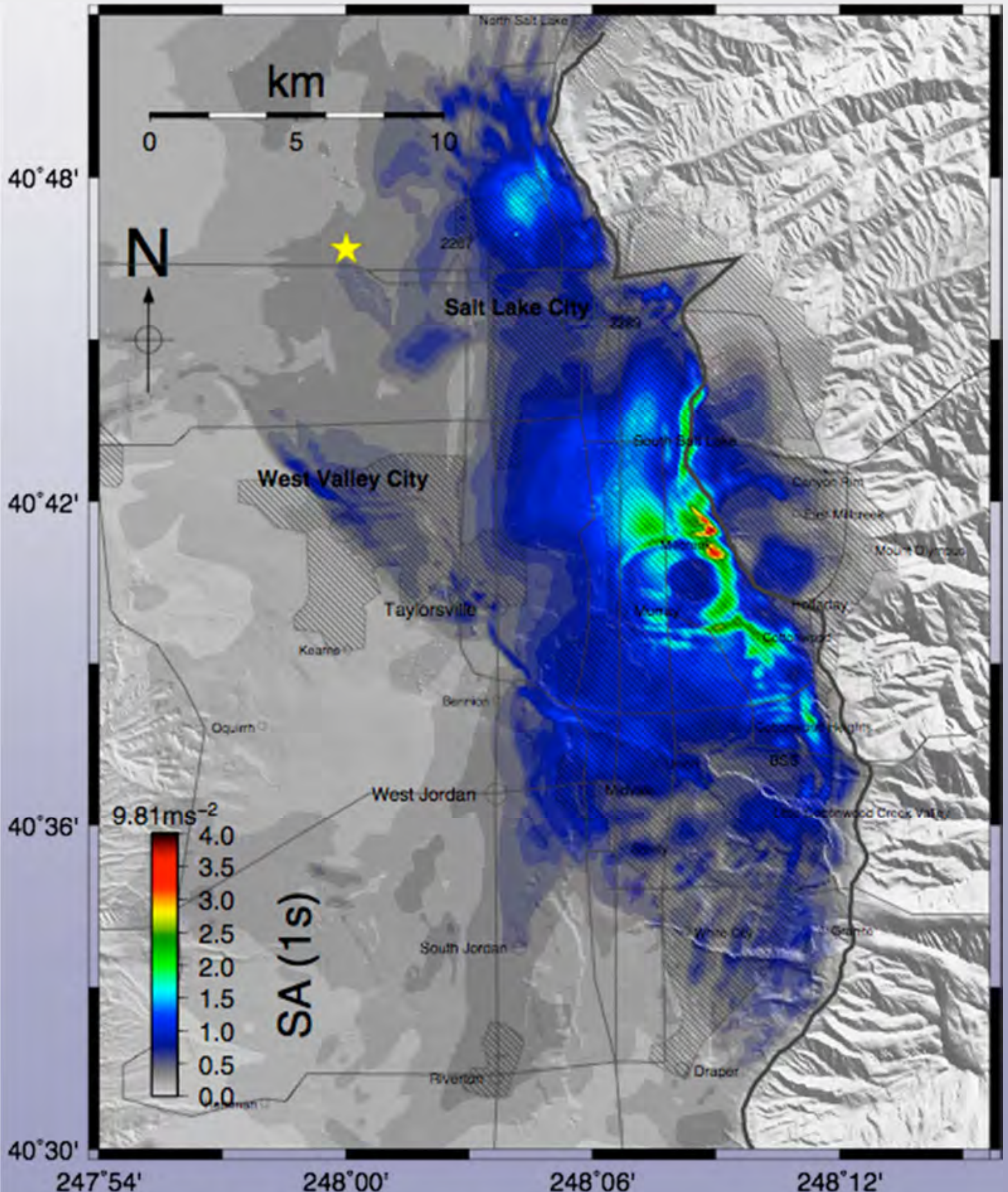
Based on long-period (0-1Hz) ground motion obtained from pseudo-dynamic scenario PDS1h0 (rupture from north to south)



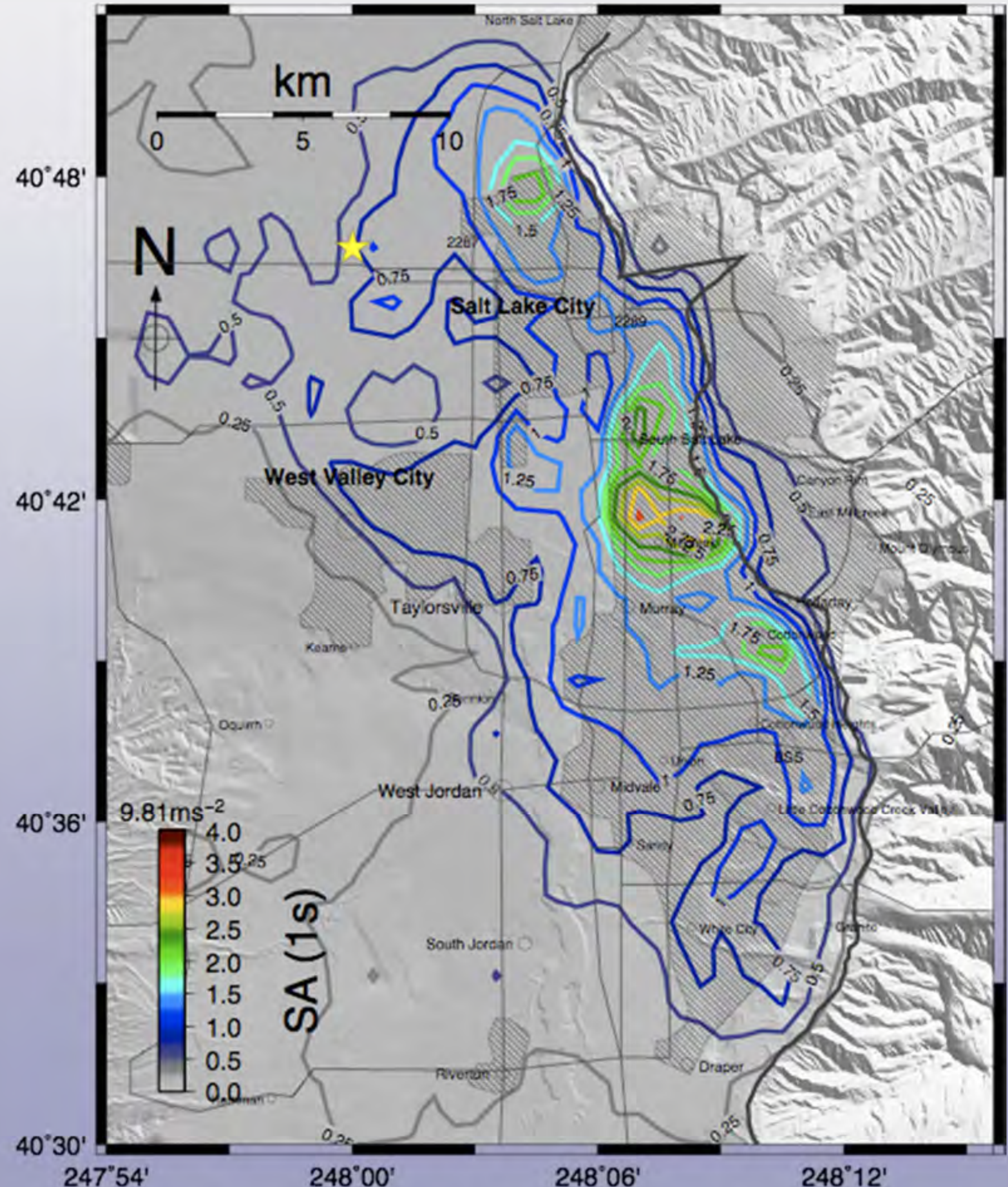


Preliminary SAs from BB Ground Motions

1s-SAs from scenario PDS1h0 (1500 x 1125 nodes)

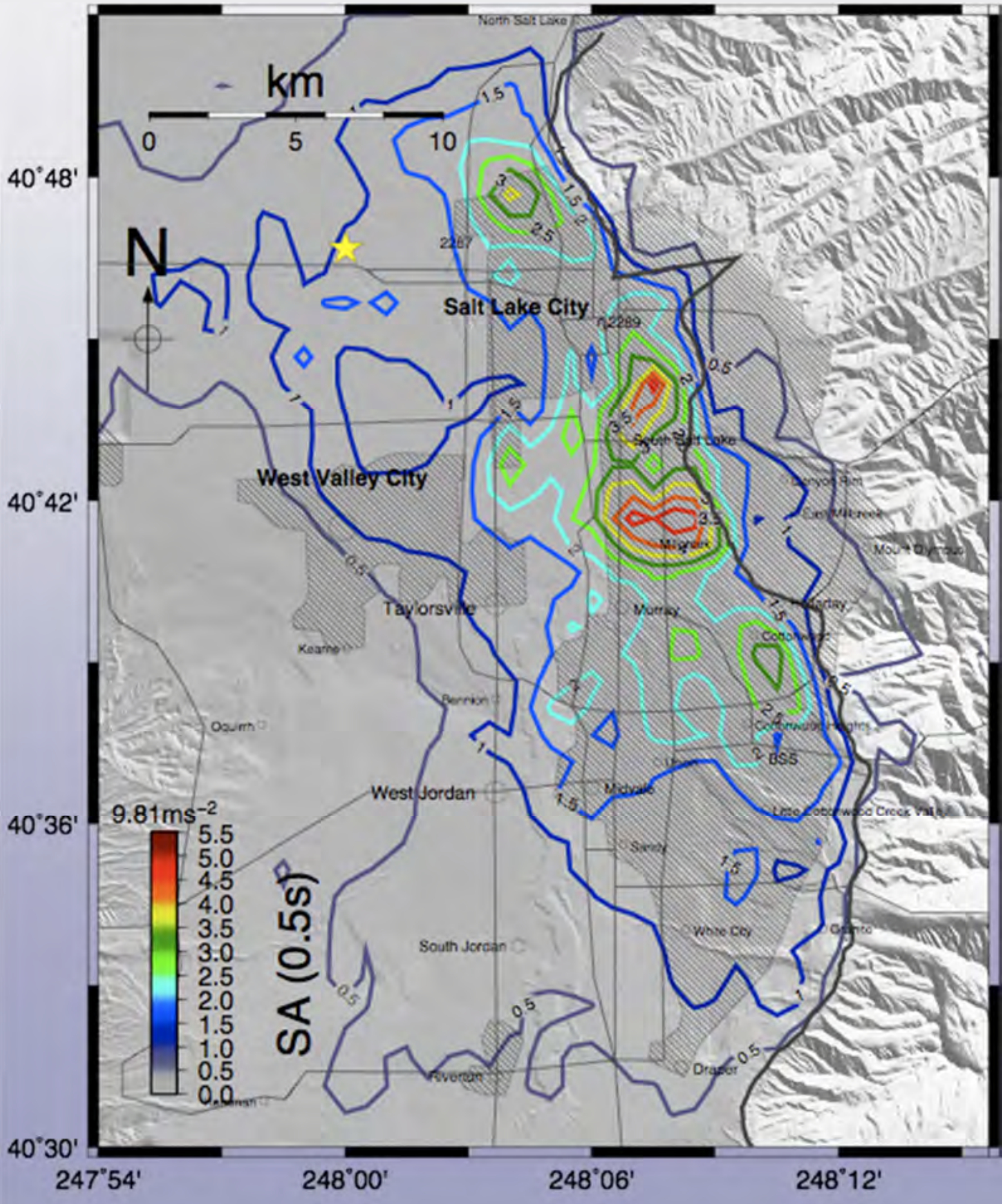


1s-SAs from BB Ground Motions (60x45 nodes)

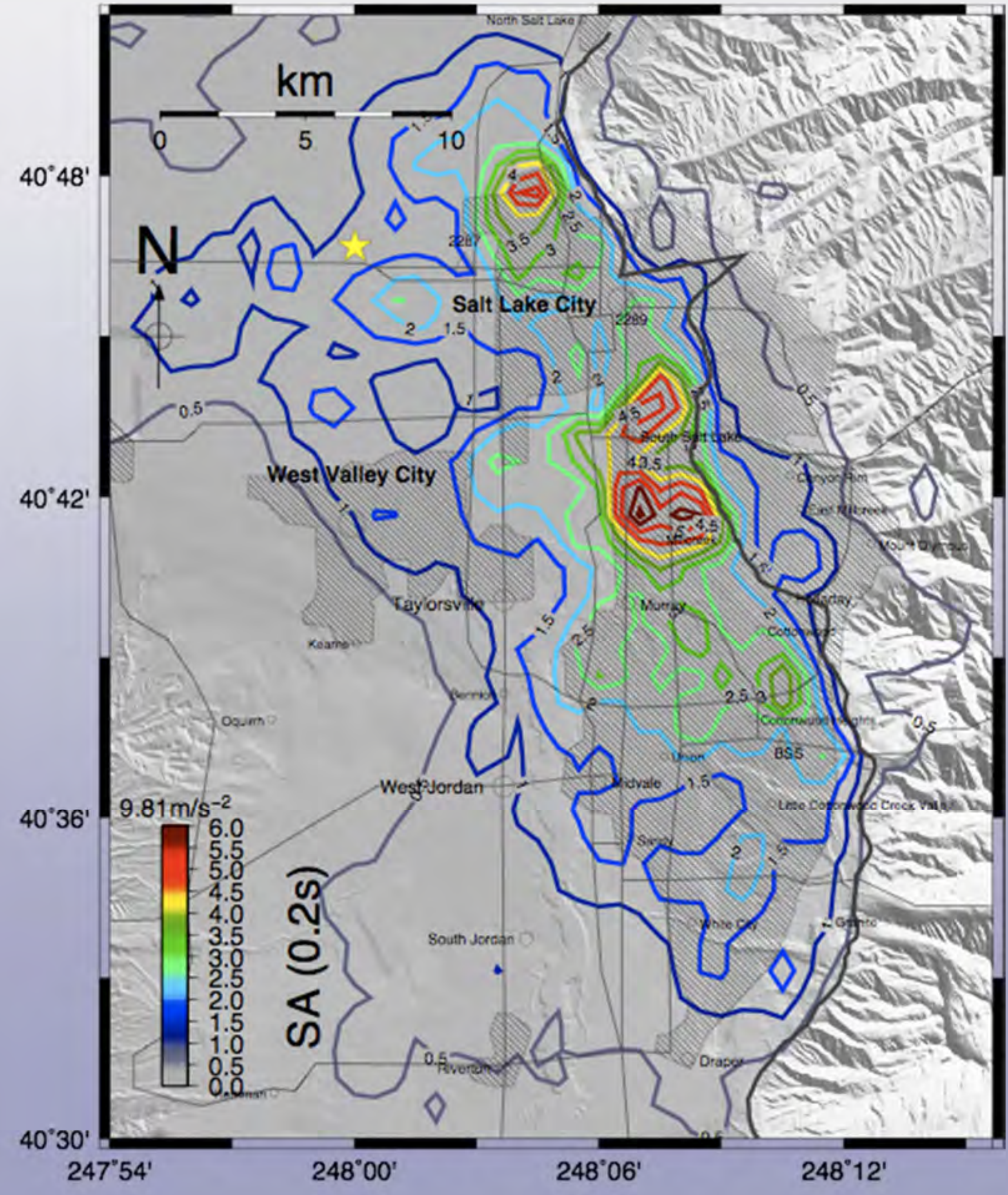


Preliminary SAs from BB Ground Motions

0.5s-SAs from BB Ground Motions (60x45 nodes)



0.2s-SAs from BB Ground Motions (60x45 nodes)



Conclusions

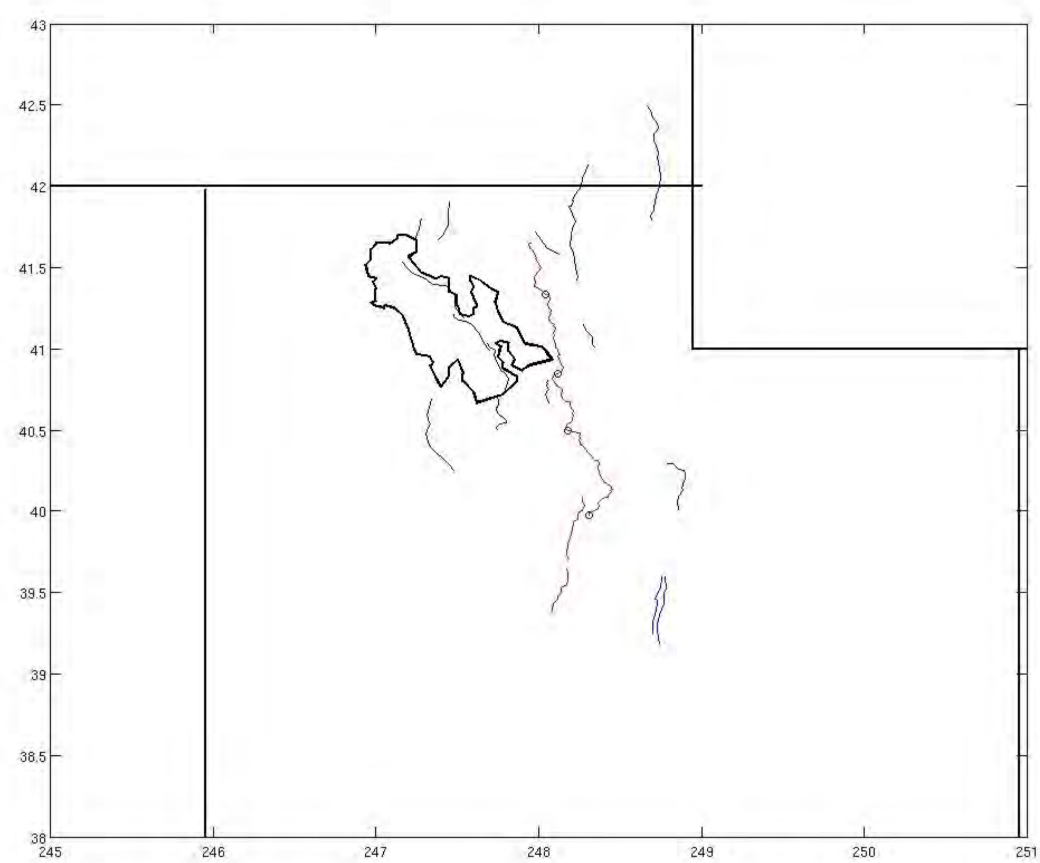
- **Validation events:**
  - Fit between observations and synthetics can be improved by increasing M_W from 3.3 to 3.6 for the Magna and Lehi events.
- **M7 scenario earthquakes**
  - The simulated ground motions (for example, 2s-SAs) include strong directivity effects (e.g., larger ground motions in the southern part of the Salt Lake Valley for rupture nucleation toward the north of the SLC segment of the WF, and vice versa).
  - Ground motions derived from dynamic rupture models yield lower ground motion than the pseudo-dynamic events.
  - Compared to the average 1s-SAs by Solomon et al. (2004) the 1s-SAs computed from three of our scenarios are comparable at some near-fault and deep-basin locations, but smaller by a factor of 2 or more at other locations.
  - 1s-SAs derived from the M7 scenario earthquakes generally within 16% POE and 84% POE predicted by empirical attenuation relationships (C&B008, B&A008).
  - 1s-SAs estimated from Solomon et al (2004) tend to be larger than 84% POE for C&B08, B&A08 for D_rup >~ 4 km. Why is that?

USGS PERSPECTIVES ON SALT LAKE CITY URBAN HAZARD MAPS

Source models
Community velocity model
Test case
3-d Simulations
Nonlinear site response
Development of maps

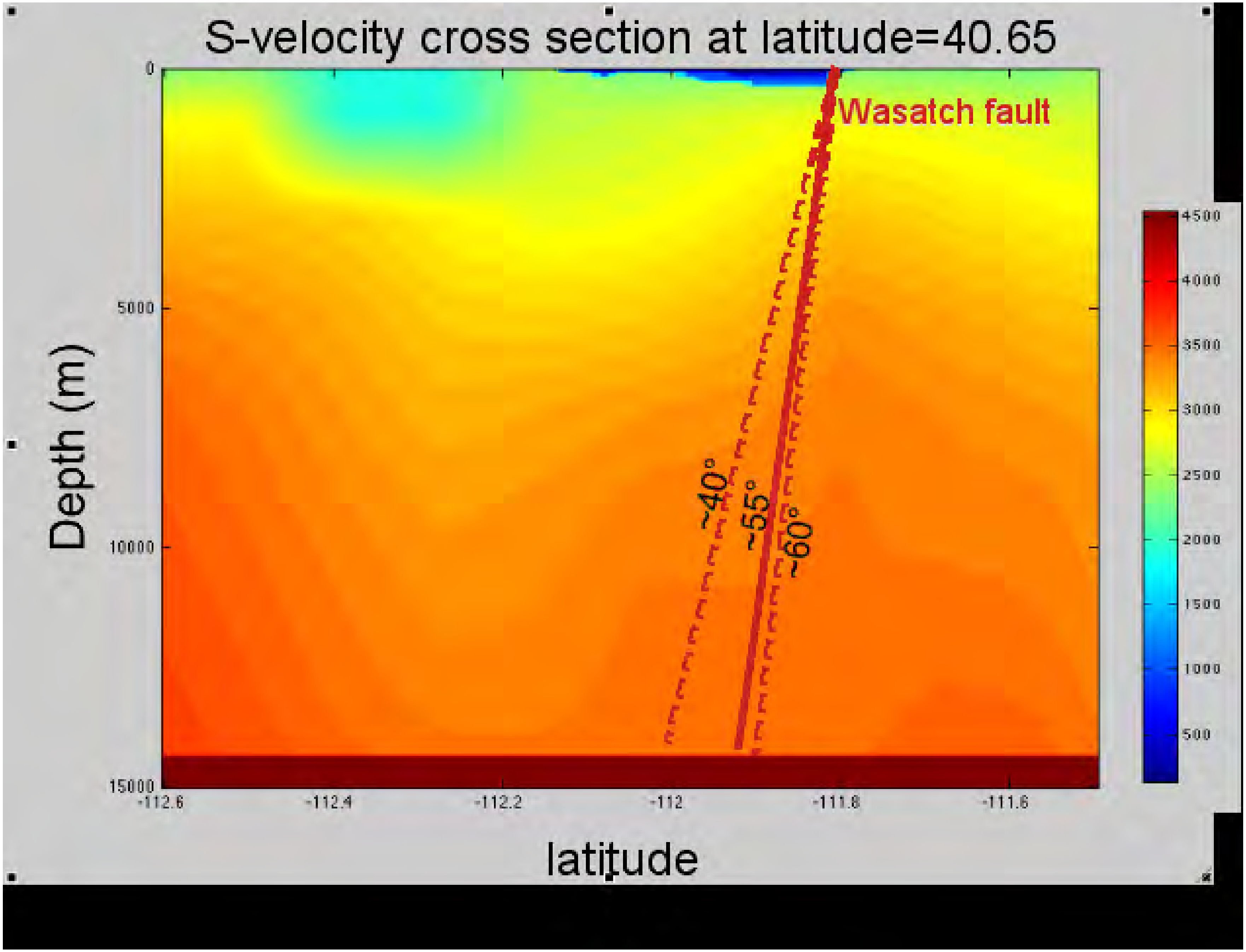
Source models

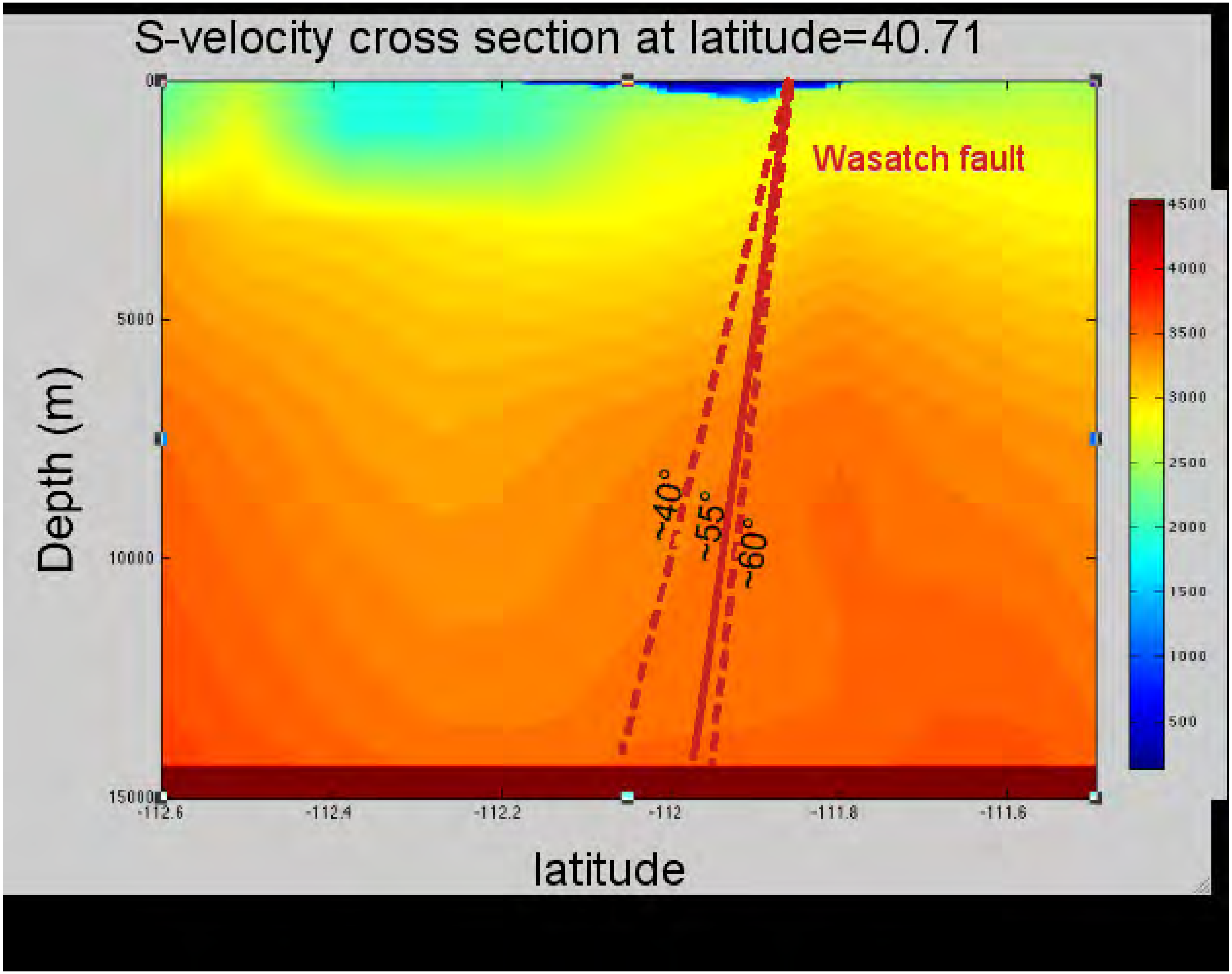
- What sources should we consider? SLC and Provo Segments?
- Dynamic rupture model (2 surface points, dip, width, magnitude of earthquake)
- Kinematic rupture (NSHMP trace, dip 55, width 18 km, M 7.0)



REVIEW OF COMMUNITY VELOCITY MODEL

Do we need a formal review?
Is the validation exercise complete?
Where is the model inadequate?


S-velocity cross section at latitude=40.65
Wasatch fault
~40°
~55°
~60°
Depth (m)
0
5000
10000
15000
-112.6
-112.4
-112.2
-112
-111.8
-111.6
latitude
4500
4000
3500
3000
2500
2000
1500
1000
500


S-velocity cross section at latitude=40.71
Wasatch fault
~40°
~55°
~60°
Depth (m)
0
5000
10000
15000
-112.6
-112.4
-112.2
-112
-111.8
-111.6
latitude
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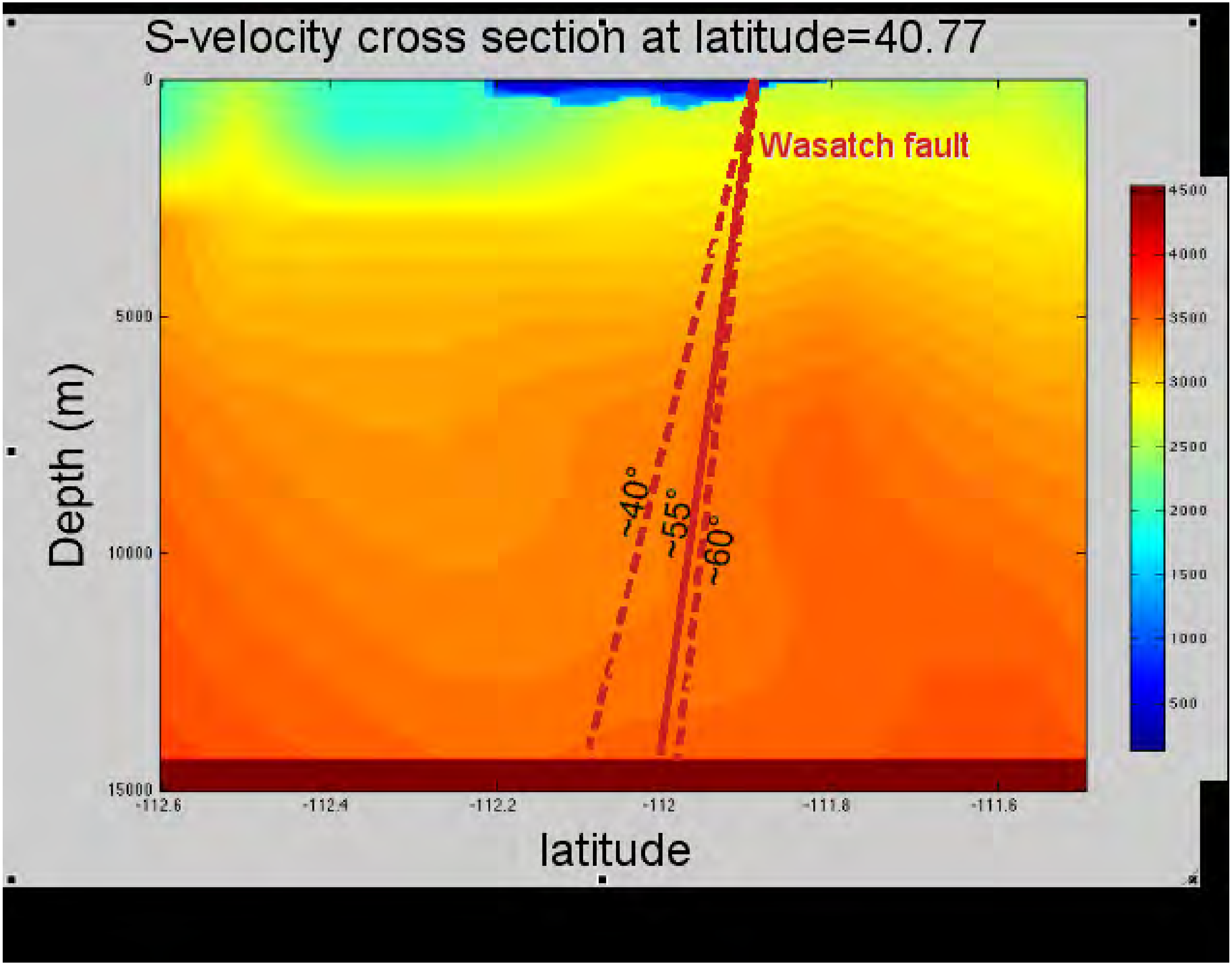
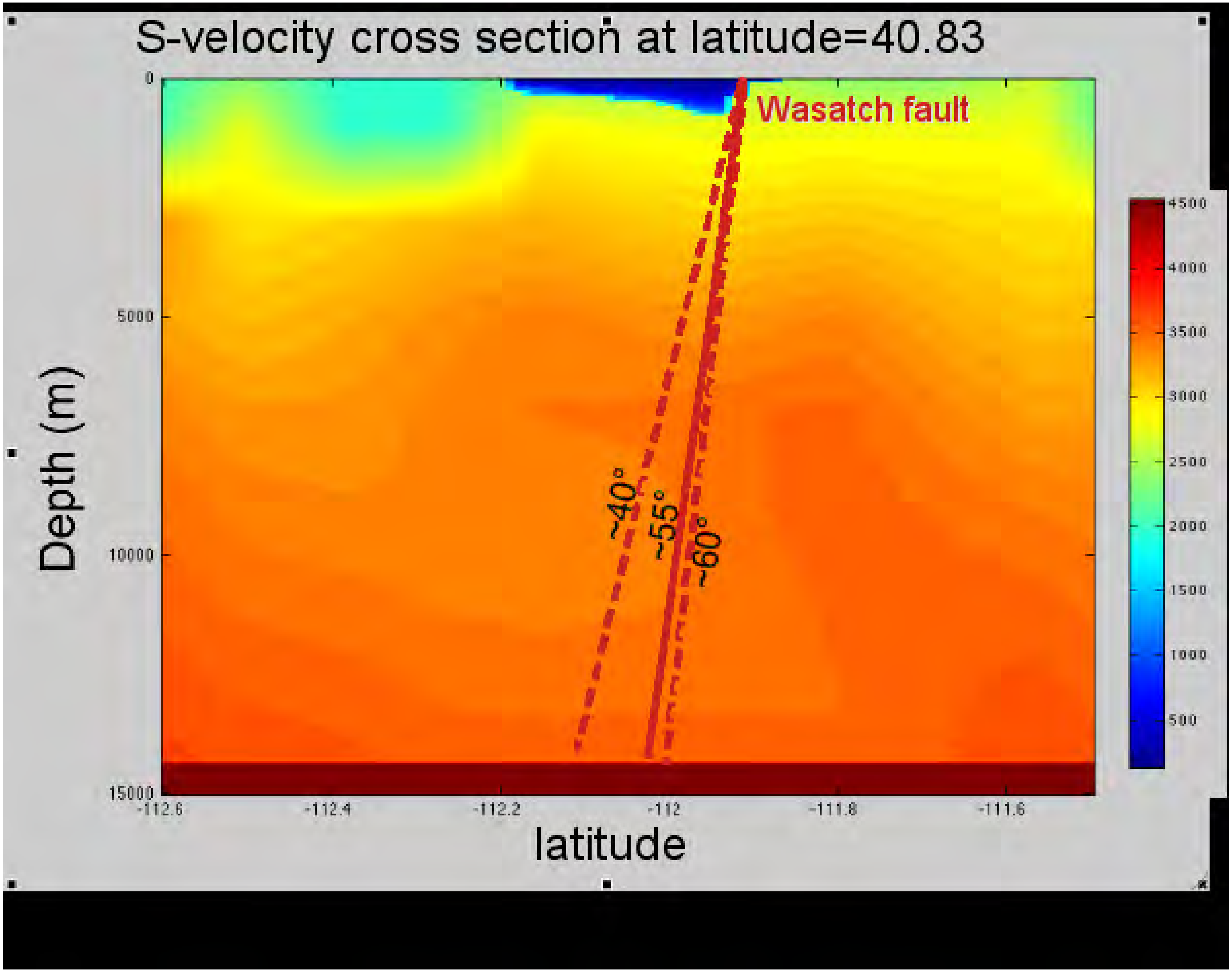
3000
2500
2000
1500
1000
500


S-velocity cross section at latitude=40.77
Wasatch fault
~40°
~55°
~60°
Depth (m)
0
5000
10000
15000
-112.6
-112.4
-112.2
-112
-111.8
-111.6
latitude
4500
4000
3500
3000
2500
2000
1500
1000
500



S-velocity cross section at latitude=40.83
Wasatch fault
Depth (m)
0
5000
10000
15000
-112.6
-112.4
-112.2
-112
-111.8
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~55°
~60°
4500
4000
3500
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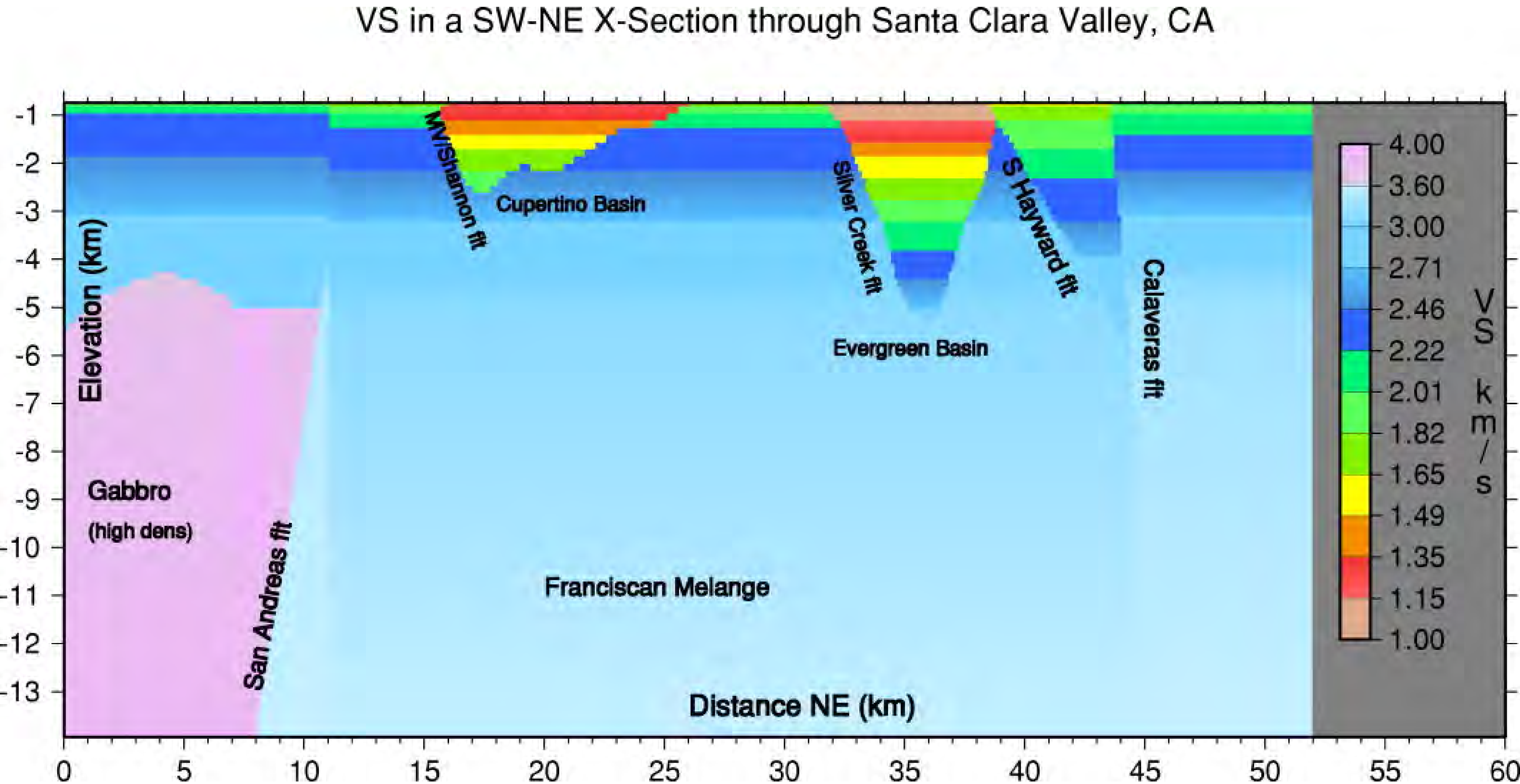
2500
2000
1500
1000
500

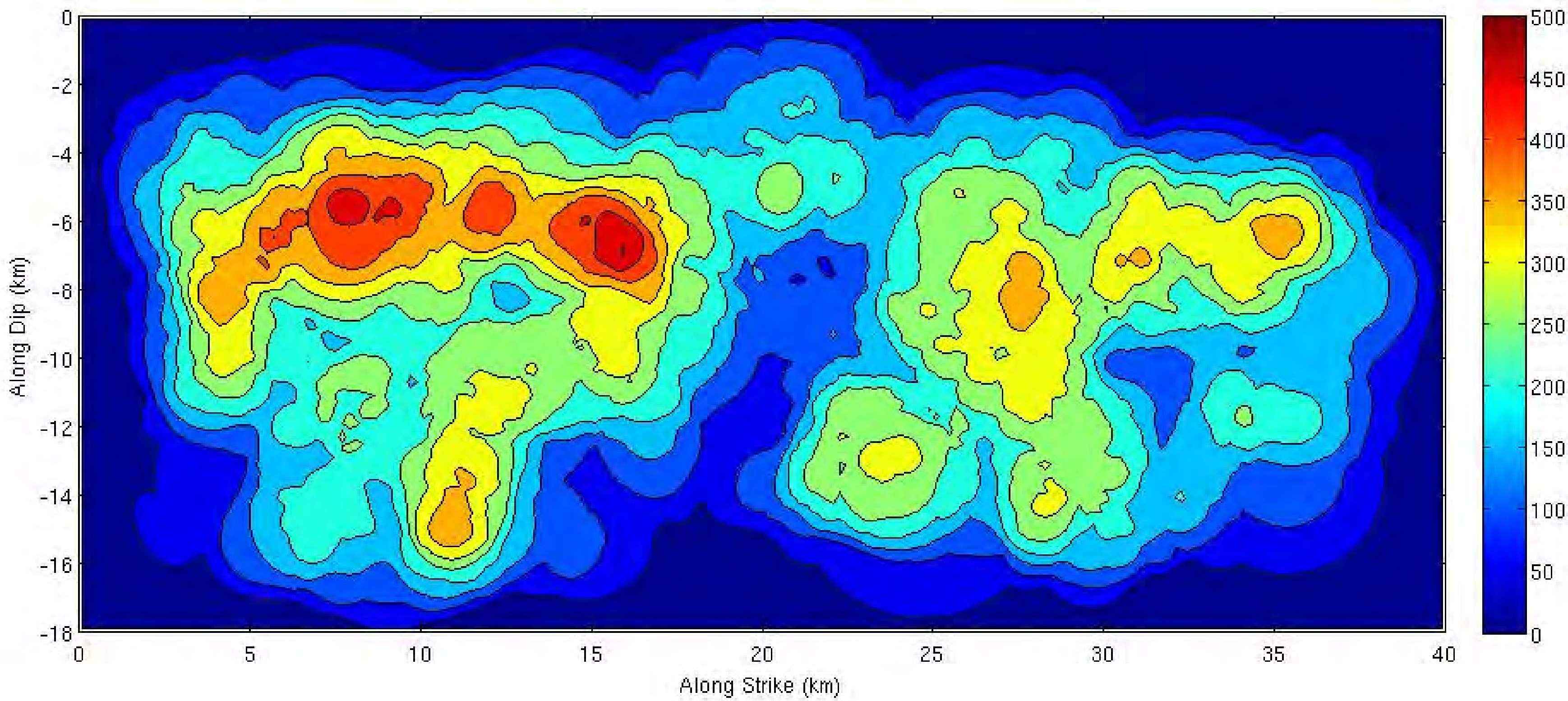


VS in a SW-NE X-Section through Santa Clara Valley, CA
Elevation (km)
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
MV/Shannon flt
Cupertino Basin
Silver Creek flt
S Hayward flt
Calaveras flt
Evergreen Basin
Gabbro
(high dens)
San Andreas flt
Franciscan Melange
Distance NE (km)
0
5
10
15
20
25
30
35
40
45
50
55
60
VS km/s
4.00
3.60
3.00
2.71
2.46
2.22
2.01
1.82
1.65
1.49
1.35
1.15
1.00

Test case (proposed)

- Kinematic rupture – define the source, slip function, rupture timing
- NSHMP fault plane
- Slip distribution (Zeng)
- Slip function (Brune, Graves – triangular, Liu – beta function)
- Rupture velocity = 2.5 km/s
- Hypocenter – North SLC segment rupture to south
- M 7.0
- Dip 55 degrees
- Depth 18
- Rake normal

Slip on fault – generated by Zeng



Calculation grid

- Calculate for sites in Salt Lake County?
- Calculate for sites in Utah County?
- Calculate for sites in Weber/Davis?

3-d Simulations

- Olsen and Pechmann (dynamic and kinematic)
- Archuleta and Smith (dynamic and kinematic)
- USGS – Harmsen, Stephenson, Zeng, Hartzell, Petersen, Leo Ramirez-Guzman (finite element)
- Other?

3-d Simulations

- What parameters should we constrain?
  - Fault geometry
  - Magnitude
  - Rupture velocity (do we want supershear ruptures?)
  - Slip distribution
  - High frequency component
- How do we incorporate dynamic models?

Non-linear amplification

- Methods – fully linear, equivalent linear?
- Modulus and Damping curves

Development of urban hazard maps

- Do we need a workshop to decide how to weight models?
- What products do we want to produce?