Summary From 2011 Meeting

Utah Ground Shaking Working Group

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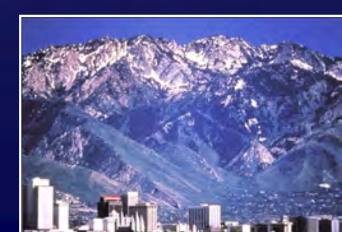
Salt Lake City, UT 14 February 2012

Summary

- The Working Group is at the point now where urban hazard maps need to be produced and released to the user community.
- An important objective is to develop a reliable 3D model to capture basin effects and incorporate them into the urban hazard maps.
- How the products are to be presented to users will be important (maps, web-based, interactive, location coordinate input/output).

Summary (cont.)

- General considerations:
  - Need maps to out to a period of 10s; PGA, 0.2s, and 1.0 SA needed for building codes.
  - Need systematic examination of uncertainties: can get at epistemic uncertainties from different modeling groups; aleatory uncertainties inherently more difficult.
  - Initial maps will be produced for Salt Lake Valley; eventually expand to other areas along the Wasatch Front.
  - Urban hazard maps need ground motion data/response spectra at each grid point.
  - Need to combine long- and short-period data – nonlinear broadband synthetics.
  - Need to assess source, path, and site response effects; produce a model and see how the user community reacts.



Summary (cont.)

- The WFCVM (version 3c) should be used be used so results from different groups can be compared. No immediate plans to update CVM. Future updates need refinement/incorporation of Q(f), kappa.

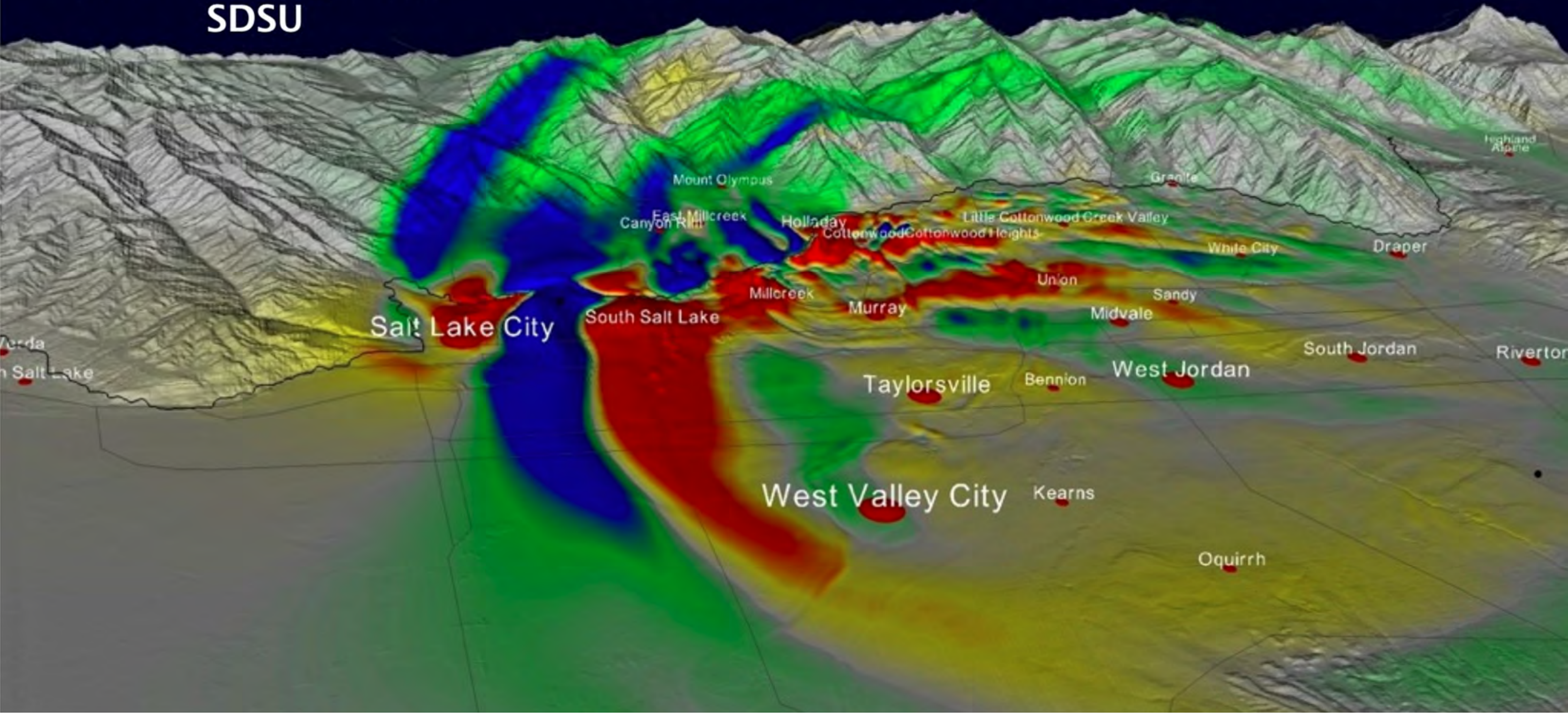
- For USGS urban hazard map products:
  - Initially try broadband deterministic maps for the Salt Lake City segment.
    - M 7.0 earthquake
    - Salt Lake basin soil properties
  - Need to validate linear results up to 2 Hz then try introducing nonlinear results.
  - Perform suite of simulations including lower Vs soils, 0.2s SA, 1.0s SA, PGA.

Ground Motion Predictions from 0-10 HZ for M7 Earthquakes on the Salt Lake City Segment of the Wasatch Fault, Utah

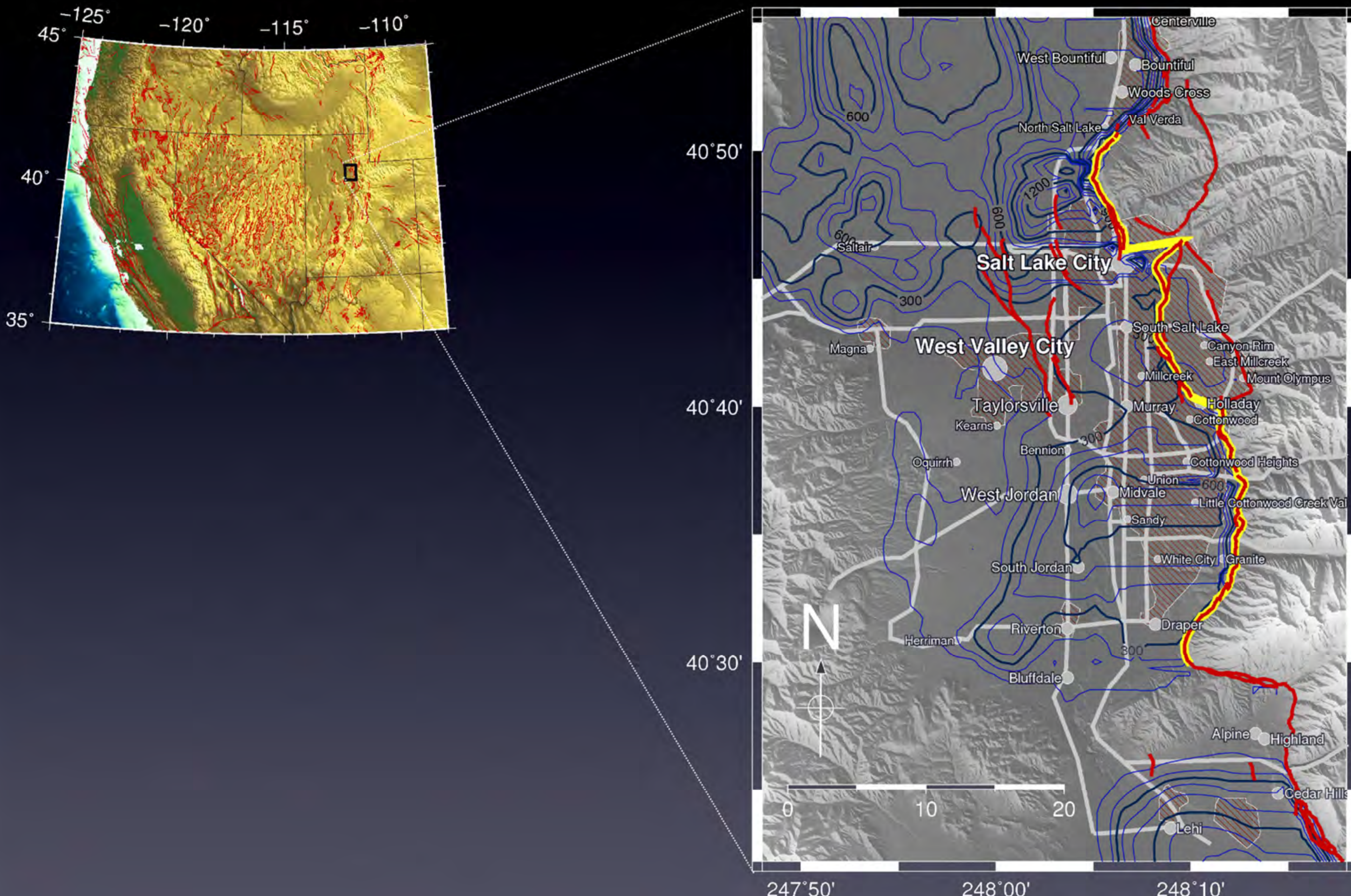
Daniel Roten
Kim B. Olsen
Harold W. Magistrale
SDSU

James C. Pechmann
University of Utah

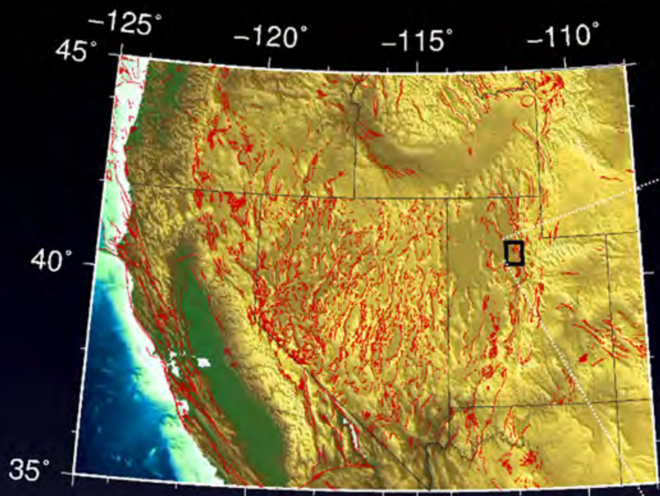
Victor M. Cruz-Atienza
UNAM

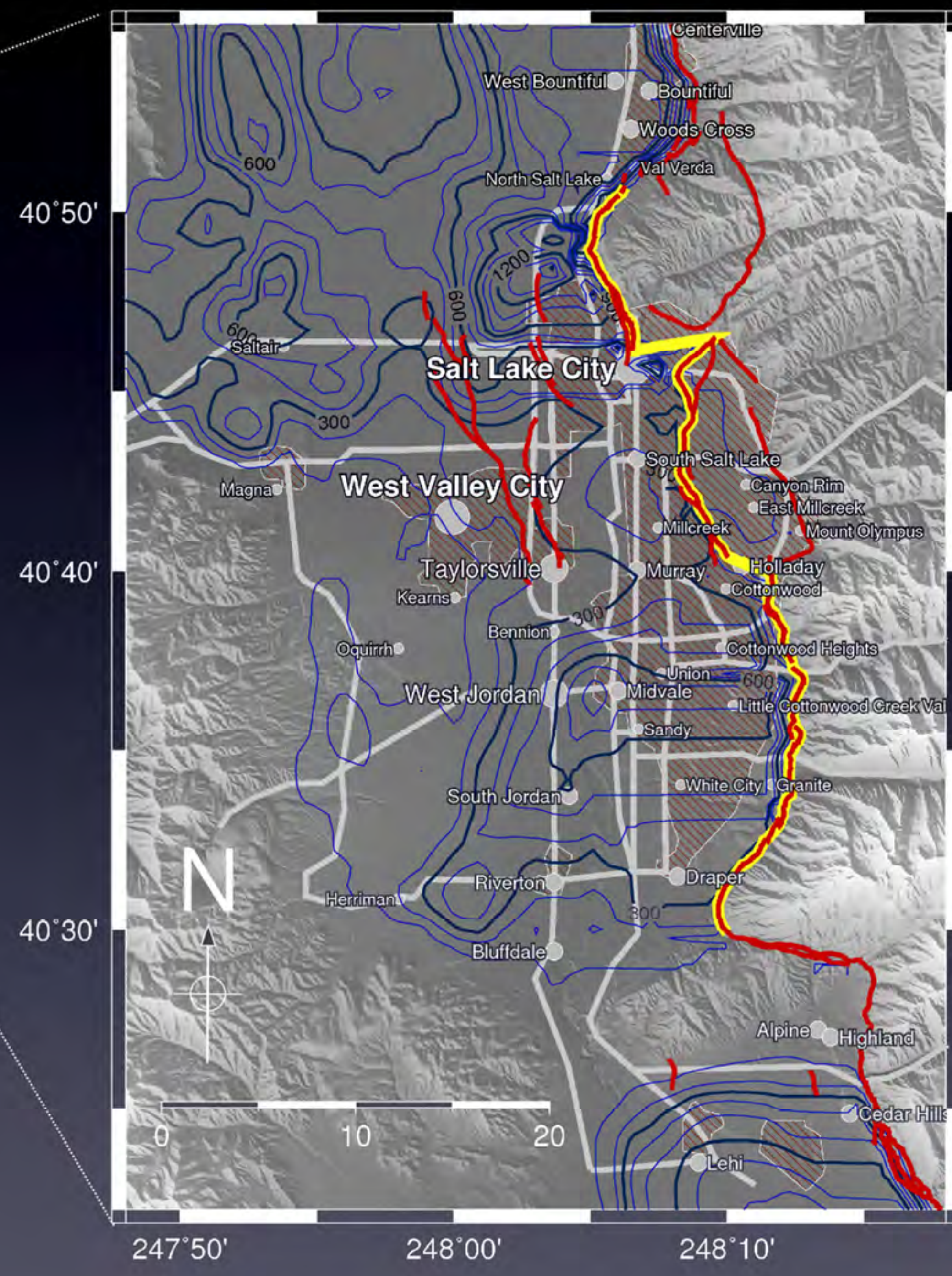


Introduction



Introduction

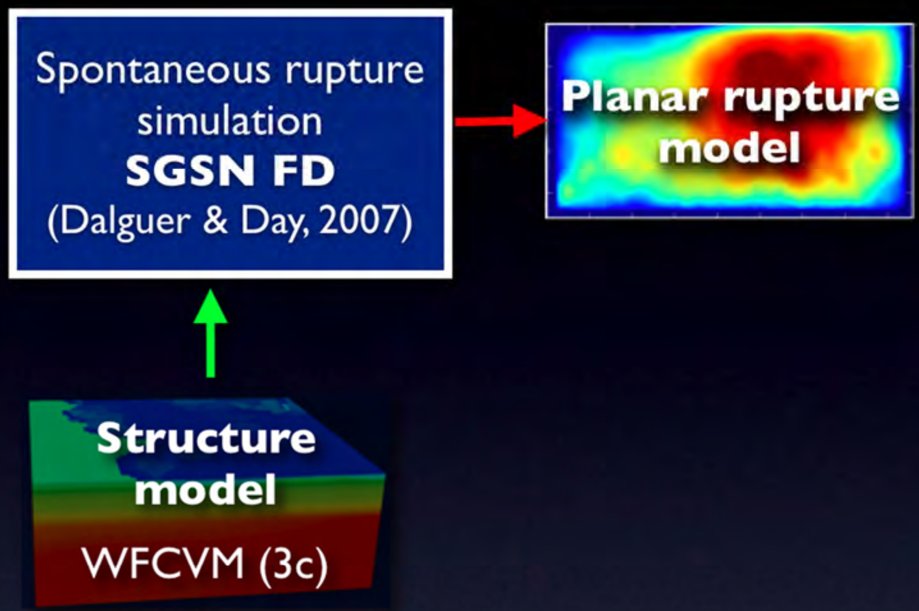




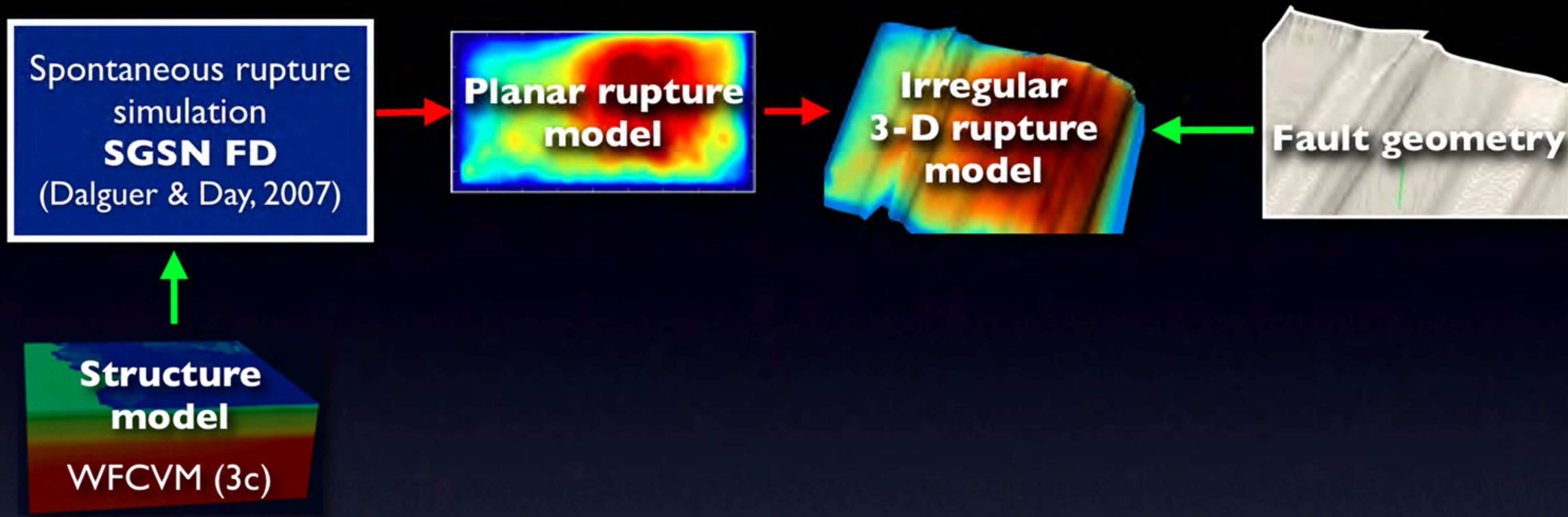
Salt Lake City segment of Wasatch Fault:

- M~7 every 1350 ± 200 years
- 16% probability of M7 event in next 100 yrs (McCalpin and Nelson, 2000)
- 6-9% probability for next 50 yrs (Wong et al., 2002)

Four-Step Method



Four-Step Method



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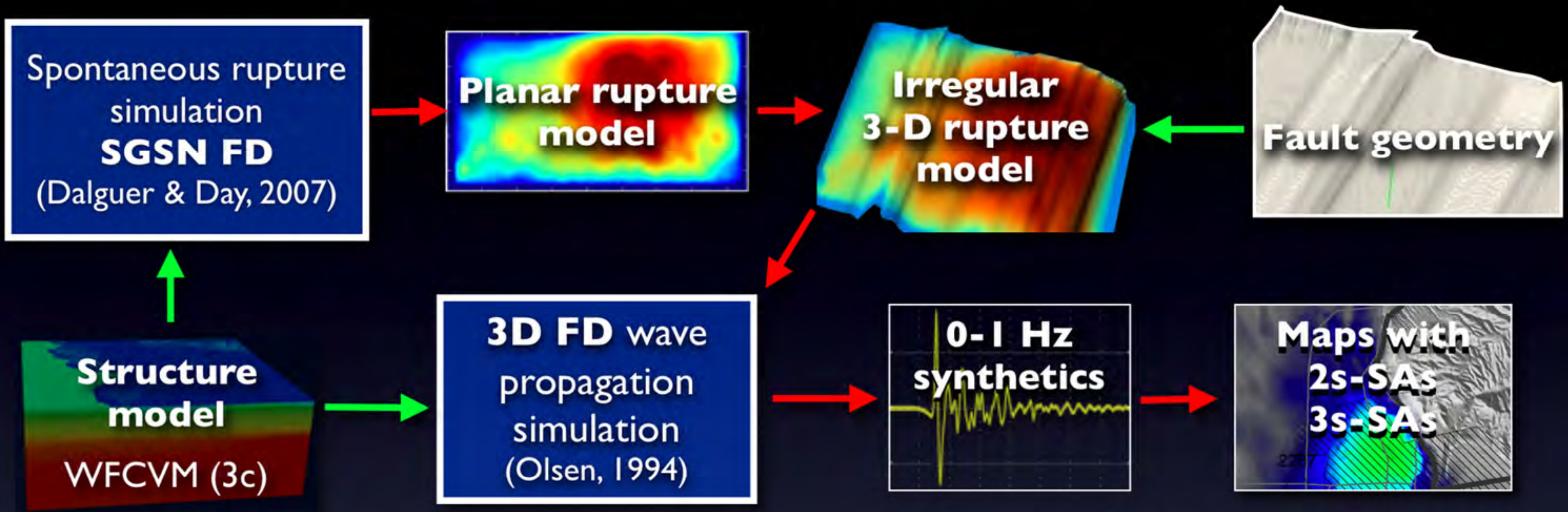

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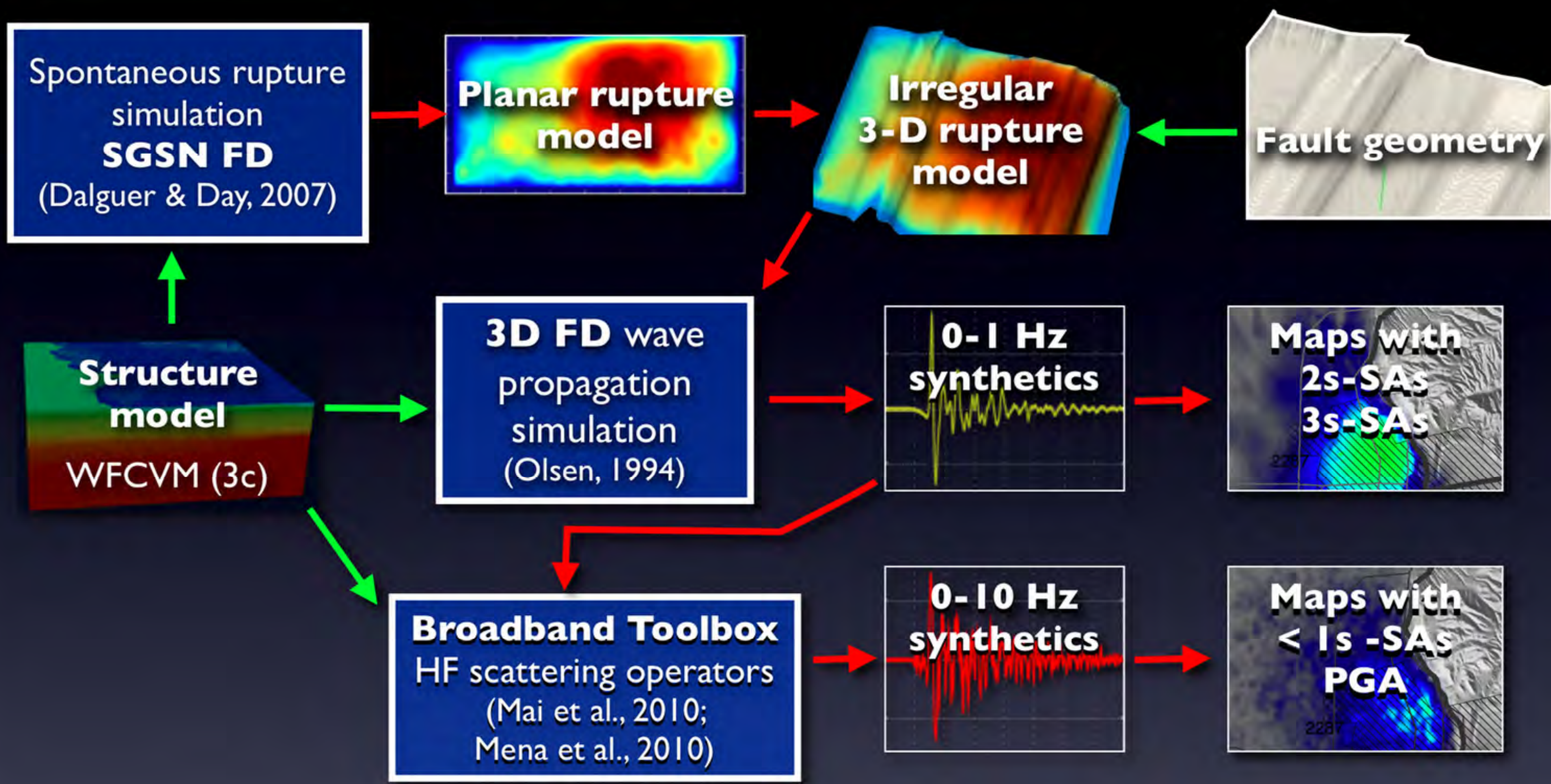

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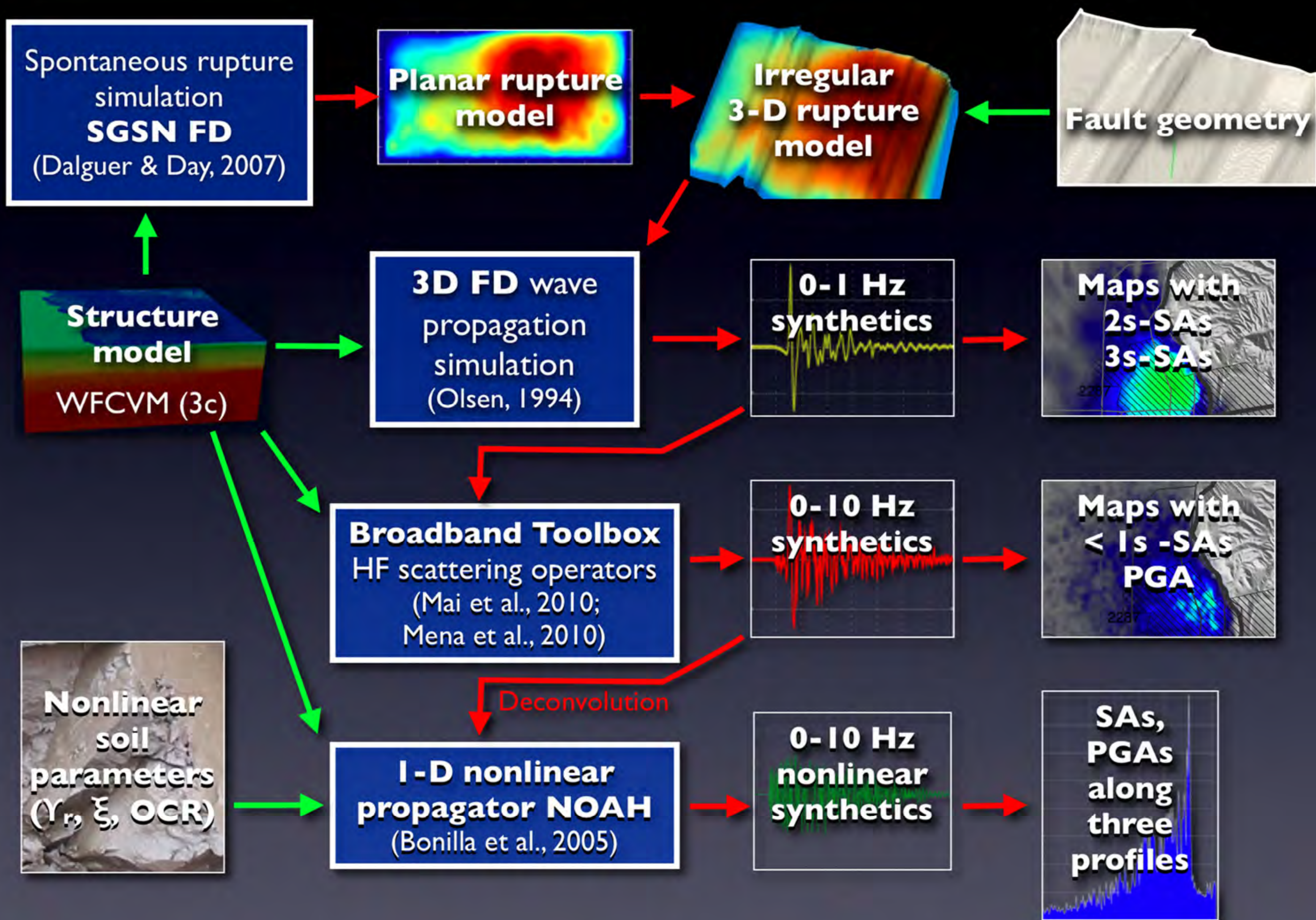

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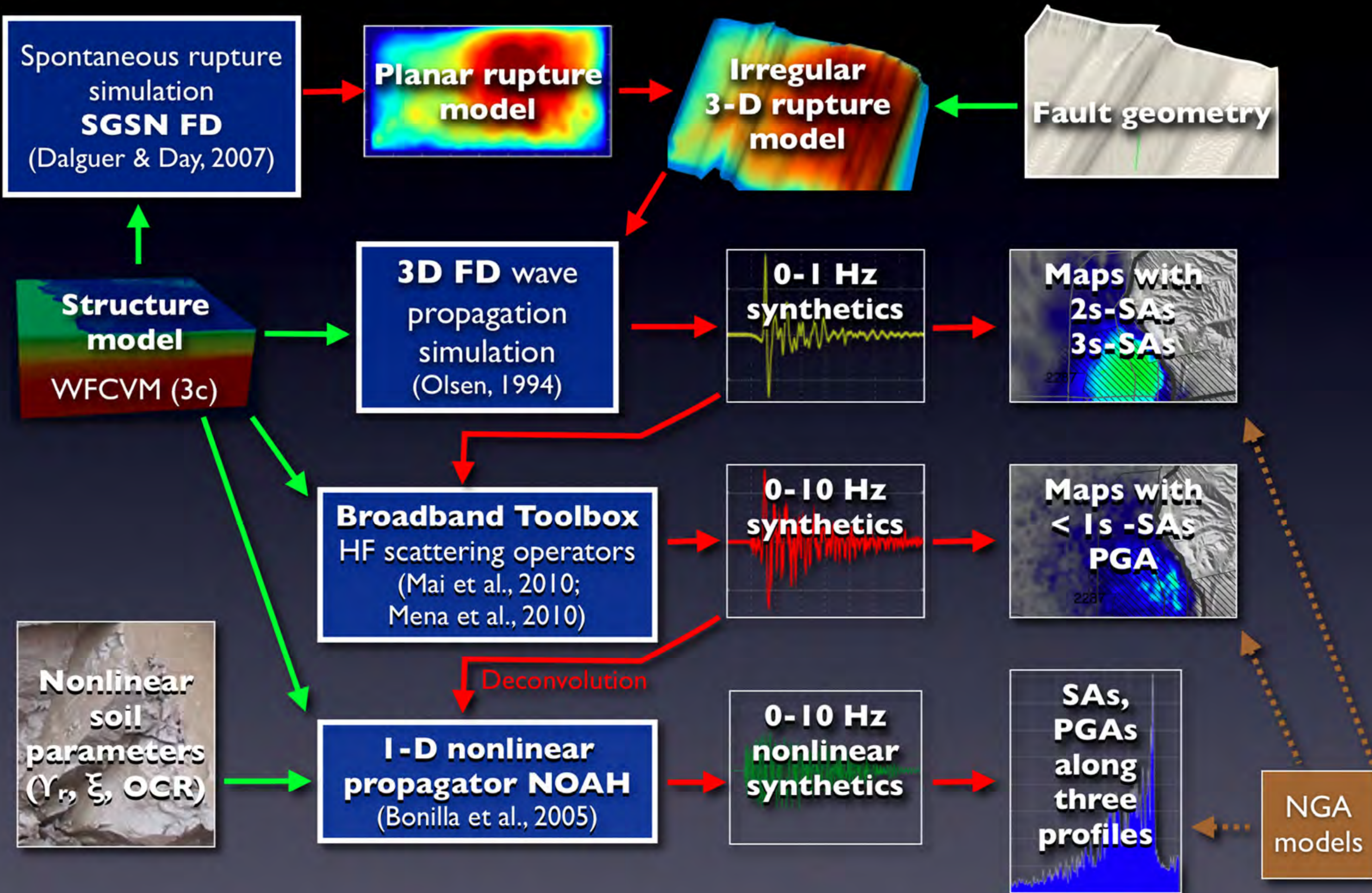
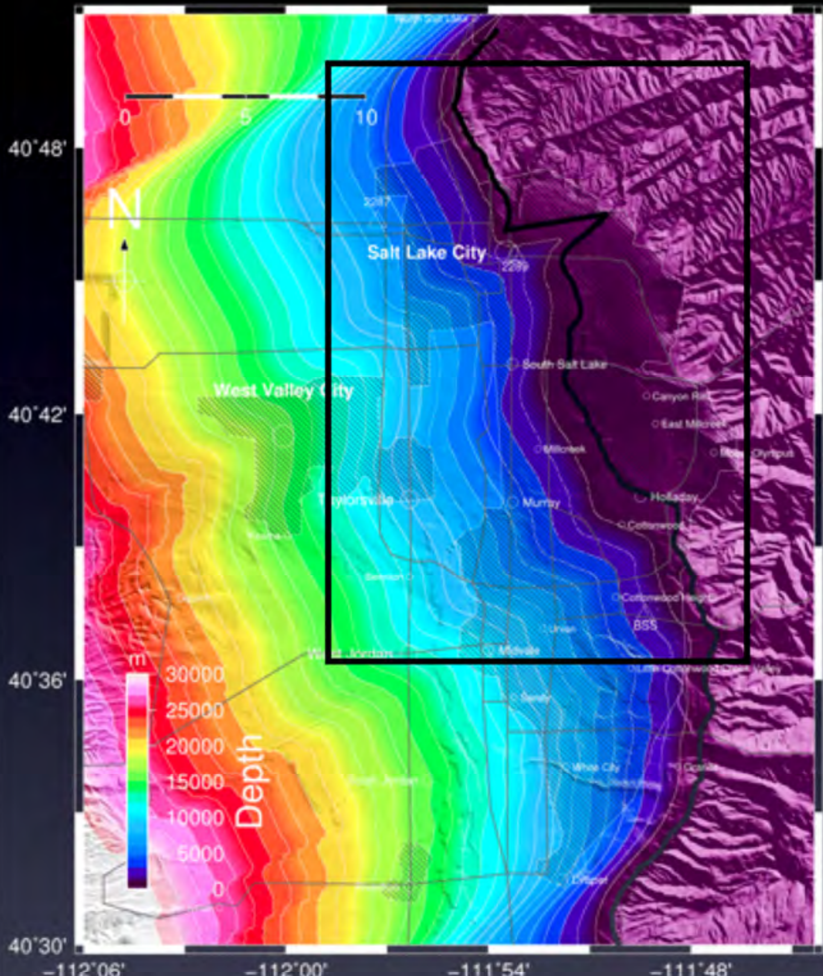
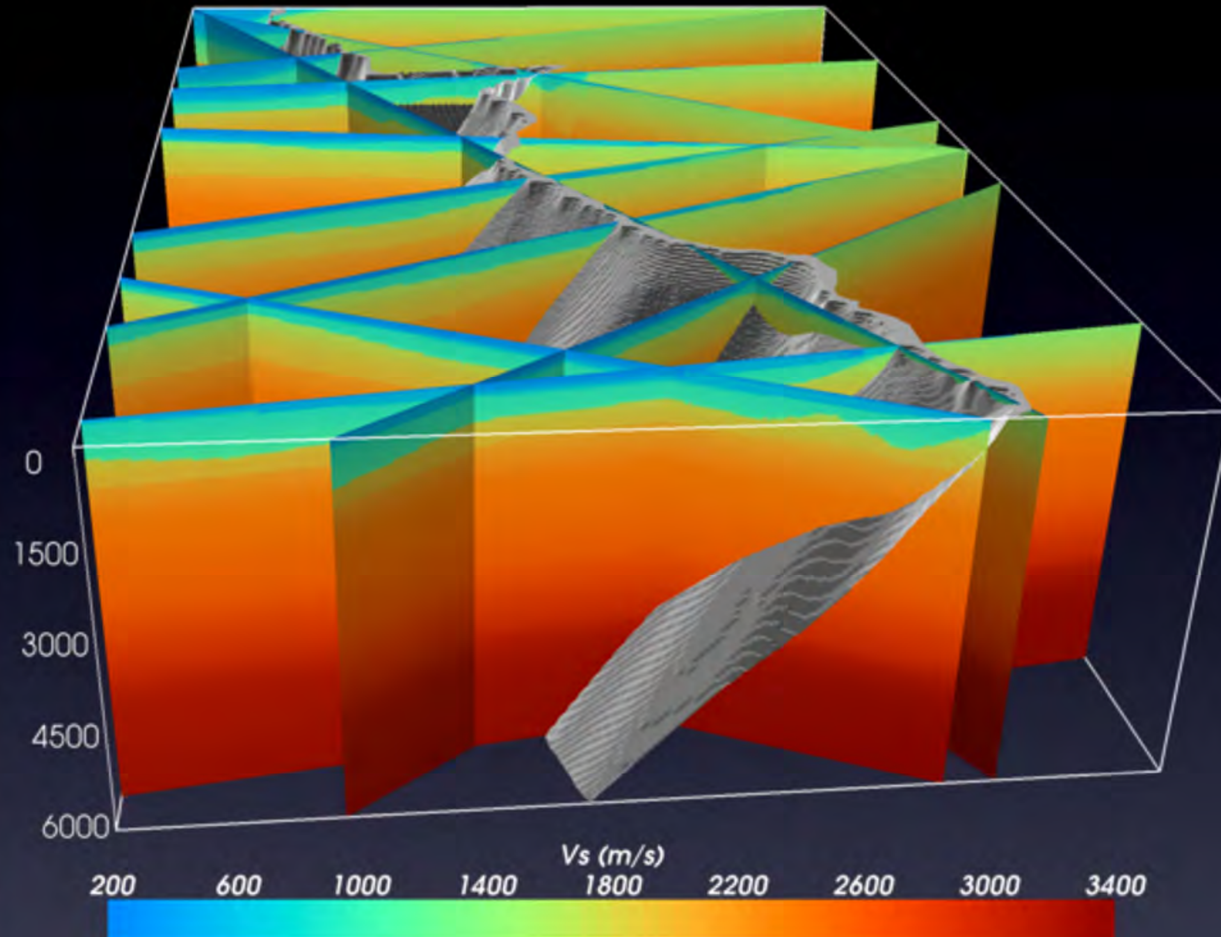


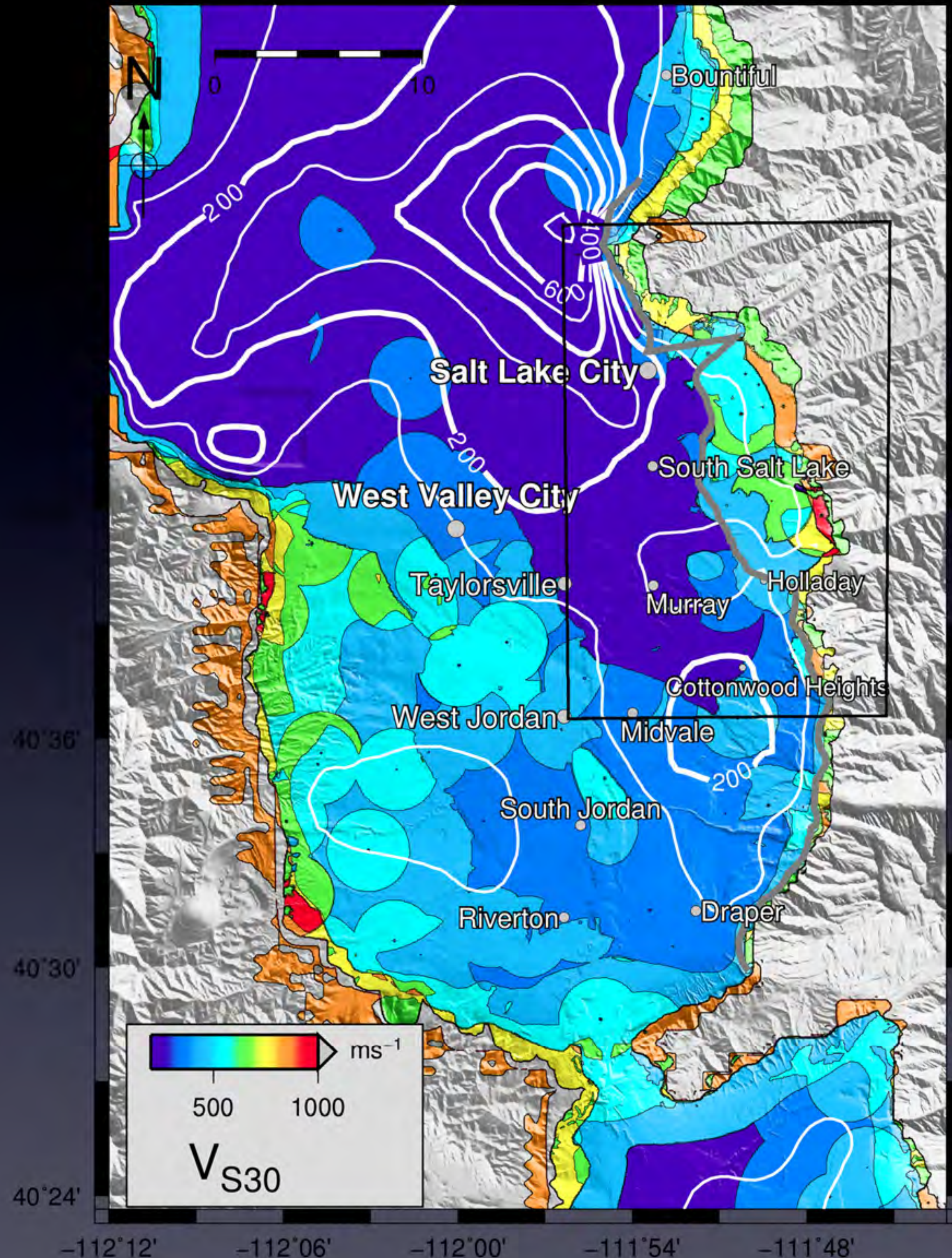
3D model of the WFSLC segment





- 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

Vs30



N
0
10
Bountiful
Salt Lake City
West Valley City
South Salt Lake
Taylorsville
Murray
Holladay
Cottonwood Heights
West Jordan
Midvale
South Jordan
Riverton
Draper
200
100
60
ms⁻¹
500
1000
V_{S30}
40˚36'
40˚30'
40˚24'
–112˚12'
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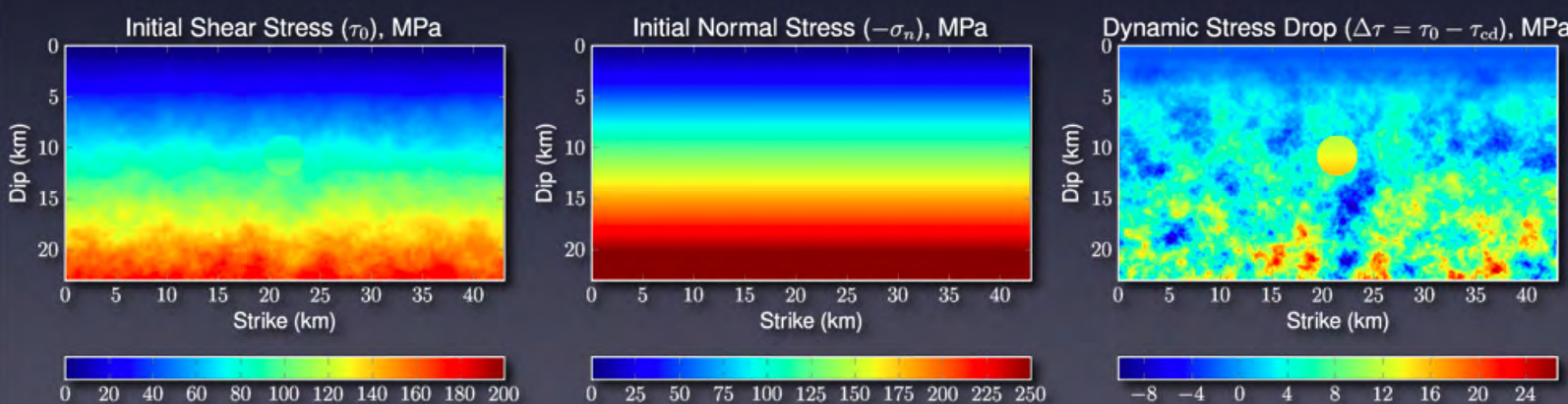
Spontaneous Rupture Models

- Simulation of dynamic rupture process on a planar vertical fault
- Staggered-grid split node finite difference method (Dalguer & Day, 2007)
- Depth-dependent normal stress (Dalguer & Mai, 2008)
- Simulated velocity strengthening near the free surface (reduce τ_0, increase d_0, $\mu_d > \mu_s$)
- Four rupture models with different hypocenter locations



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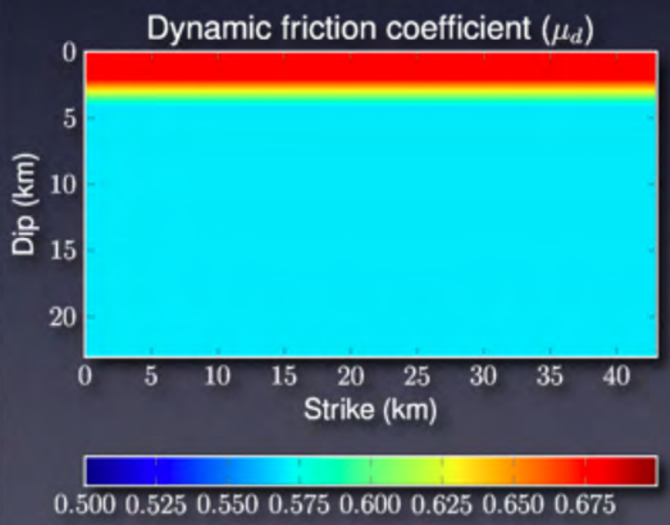
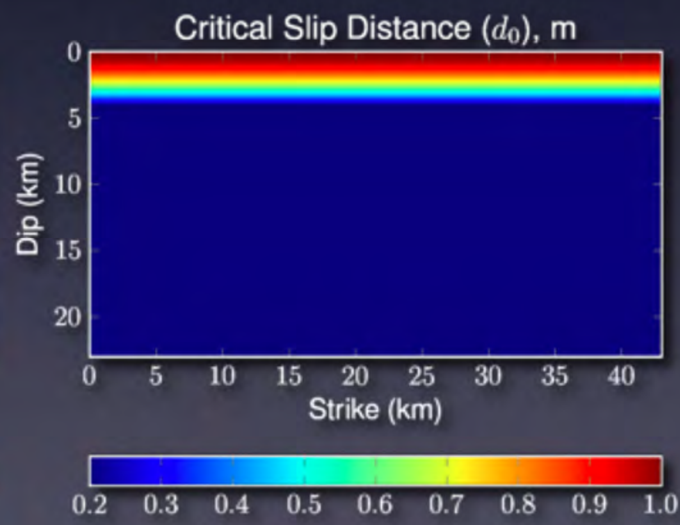
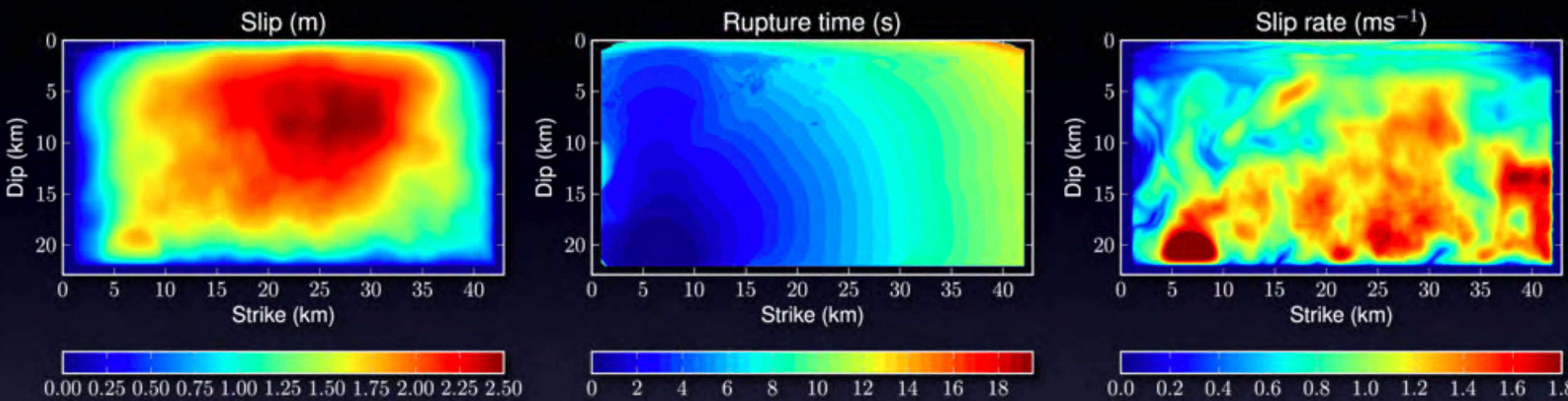


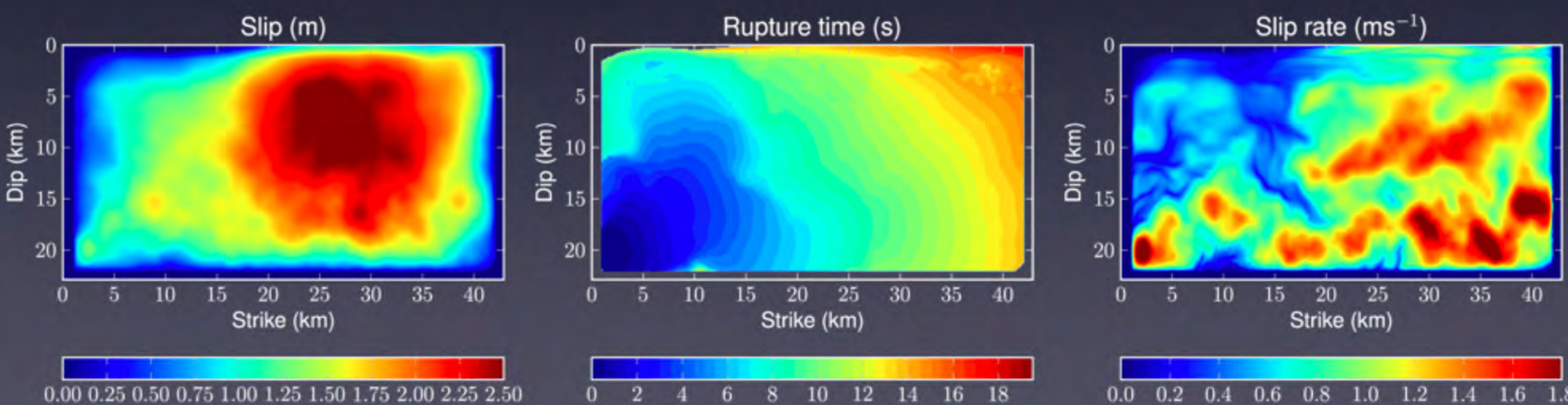


Spontaneous Rupture Models

Scenario A

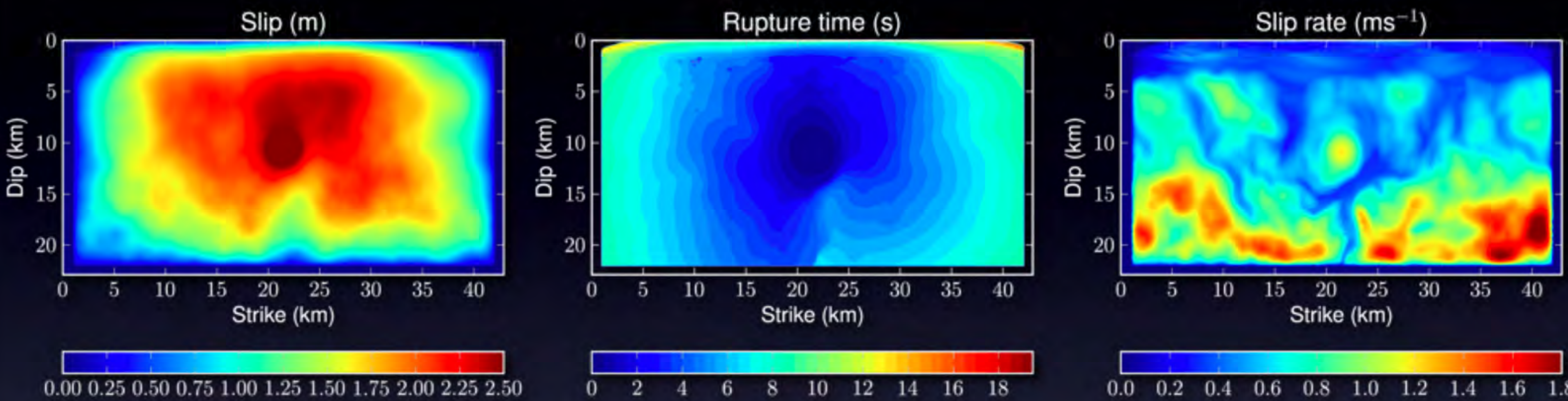


Scenario B

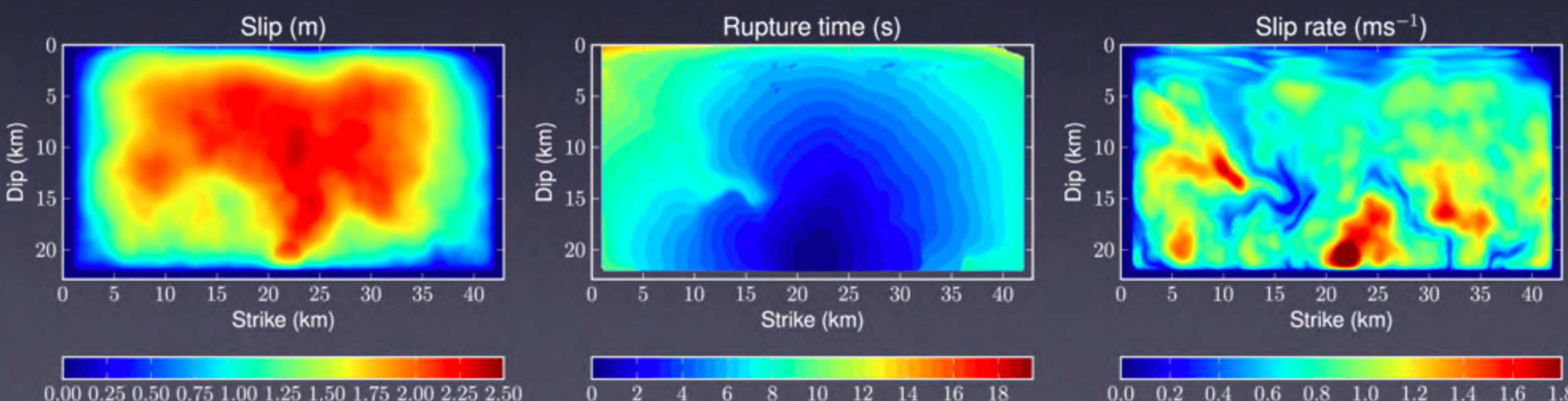


Spontaneous Rupture Models

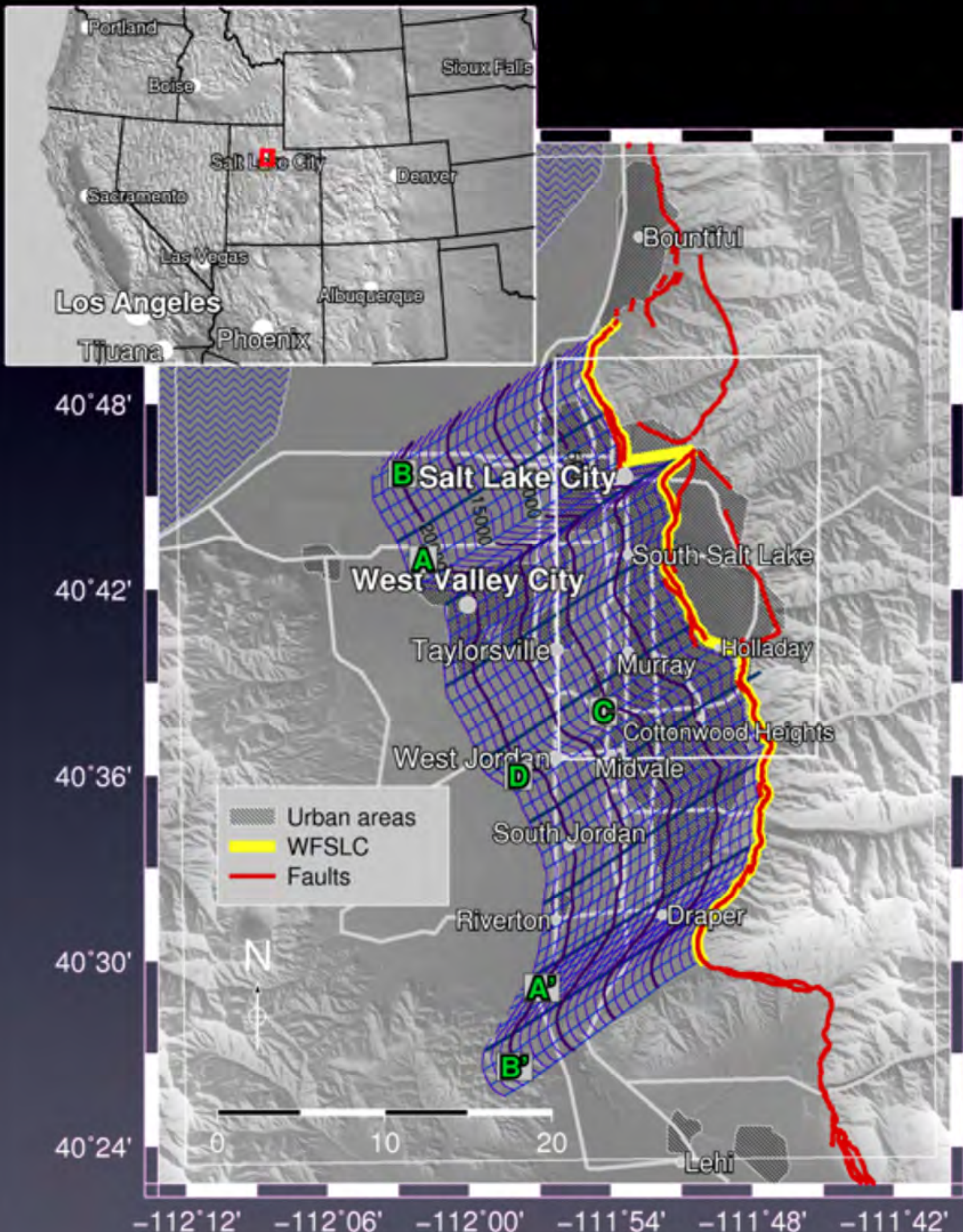
Scenario C



Scenario D



Six scenario EQs



Representative distribution of hypocenter locations:

Normal faulting EQs tend to originate near brittle-ductile transition zone (~15 km depth):

- 5 deep hypocenters (20 km down-dip)
- 1 shallower hypocenter (10 km down-dip)

Rupture tends to start near non-conservative barriers:

- near northern end (A, B)
- near southern end (A', B')
- near bifurcation near Holladay stepover (C, D)

(Bruhn et al. ,1992)

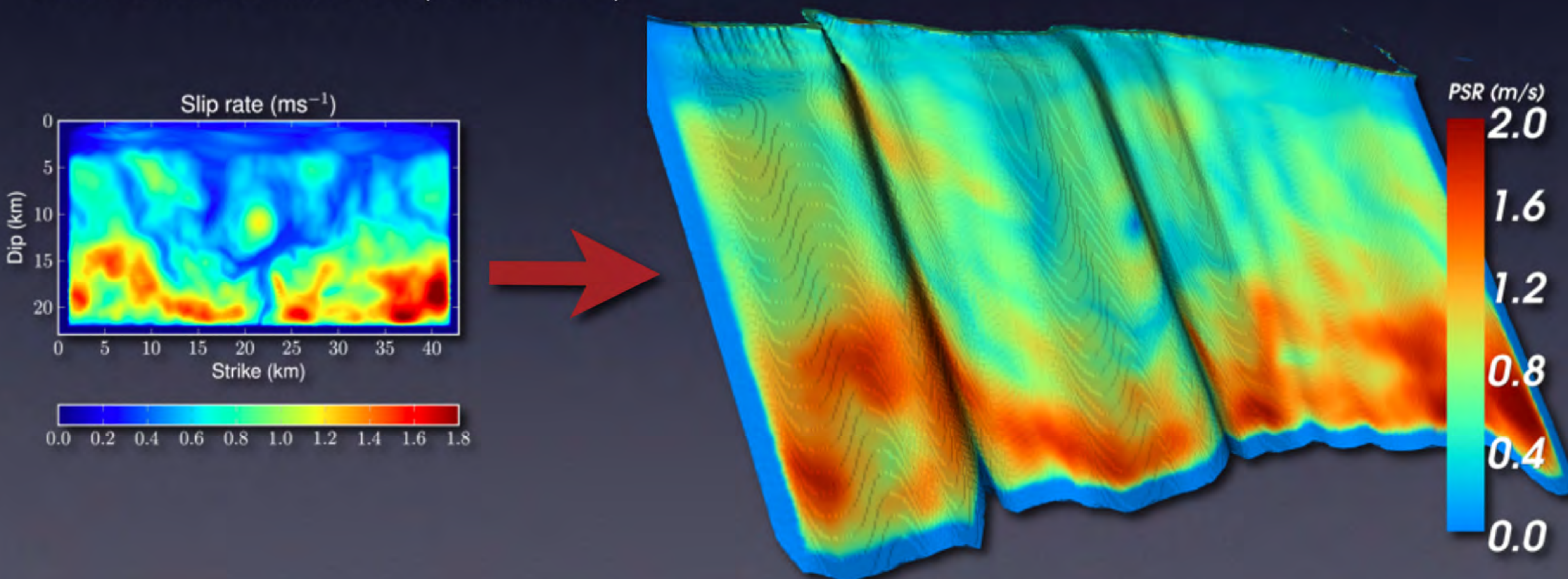
FD Simulation of Wave Propagation

- Planar rupture models are projected onto irregular 3-D model of the WF and the moment rate time histories are inserted into grid nodes

- Two of the four rupture models are mirrored laterally, yielding six source models

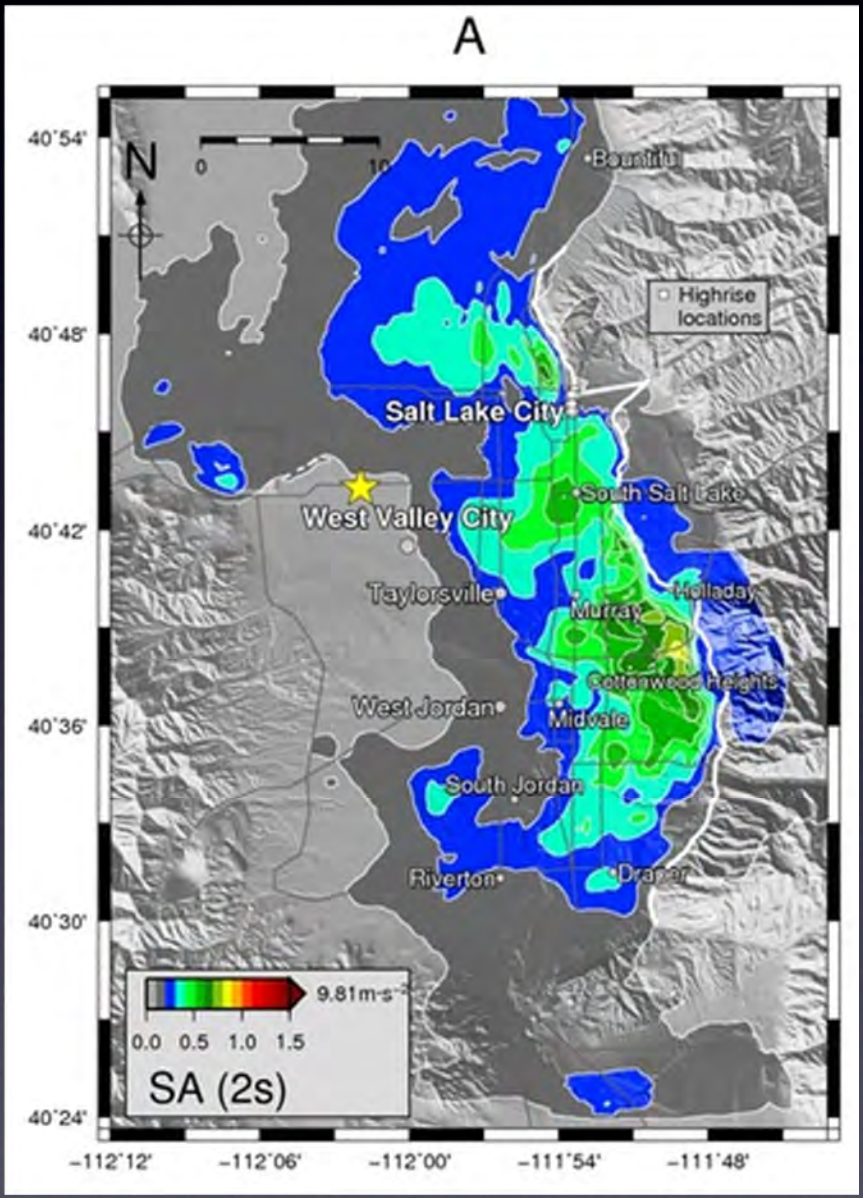
- Wave propagation of these source models is simulated with velocity-stress staggered-grid finite difference method (Olsen, 1994)

FD3D parameters	
Model dimensions	1500 x 1125 x 500
Simulation length	60s (24,000 iter.)
Discretization	40m / 0.0025 s
Minimum V_S	200 ms^{-1}
Highest frequency	1 Hz
# of CPU cores	1875
Wall-clock runtime	2.5 hrs (NICS Kraken)

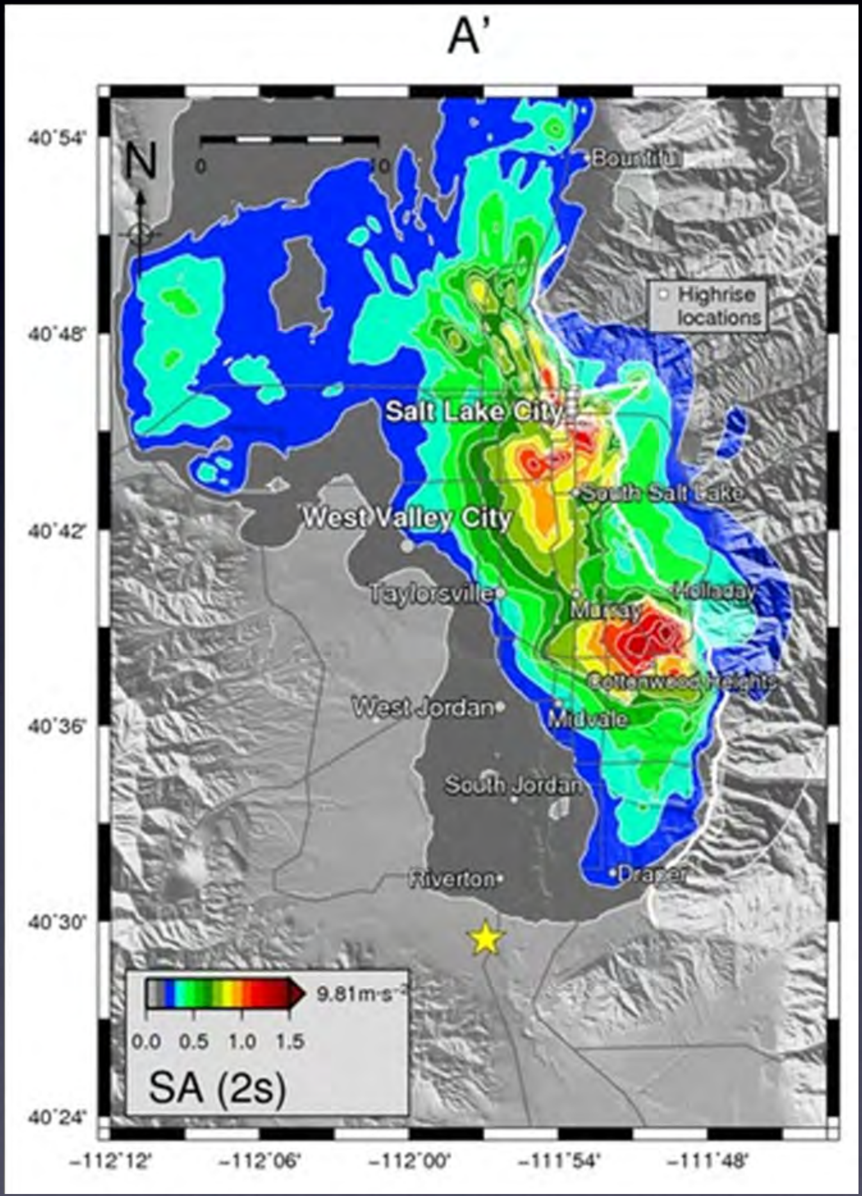


Spectral Accelerations at 2s (2s-SAs)

Scenario 2a

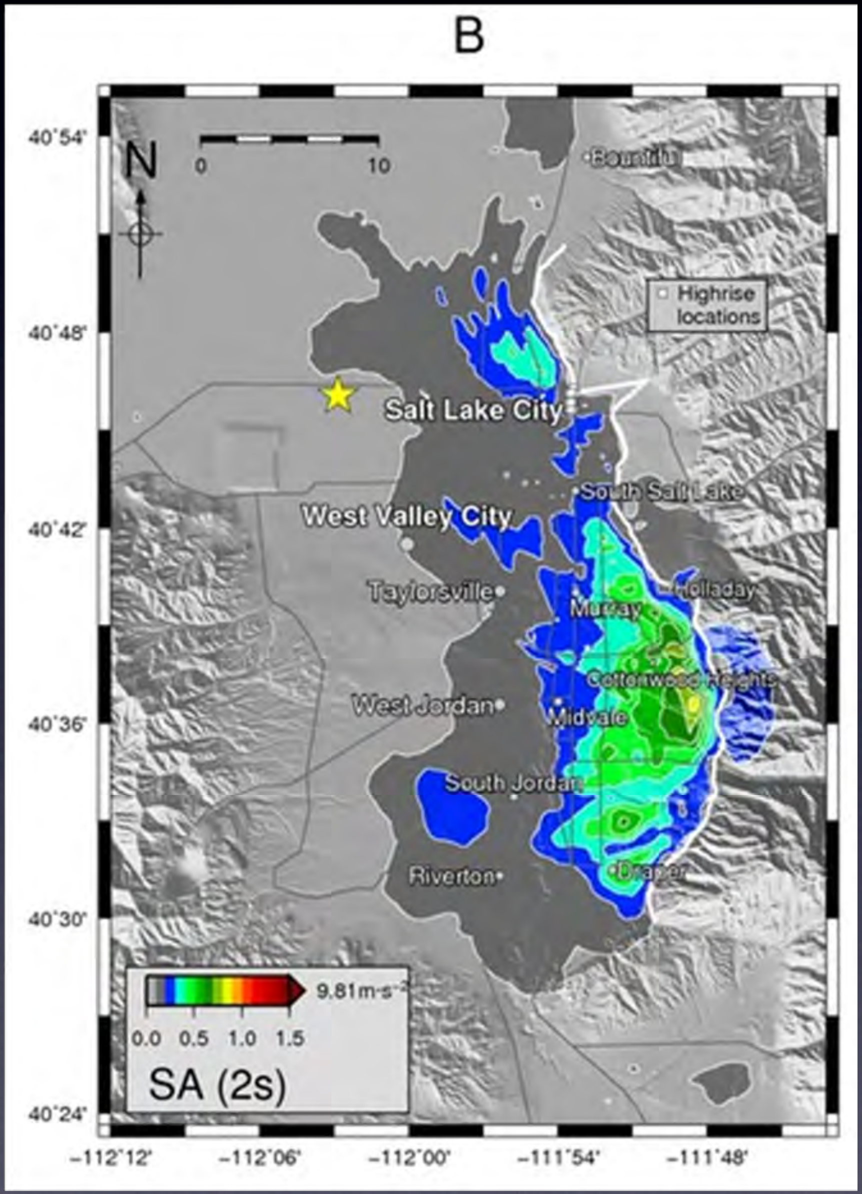


Scenario 2aM

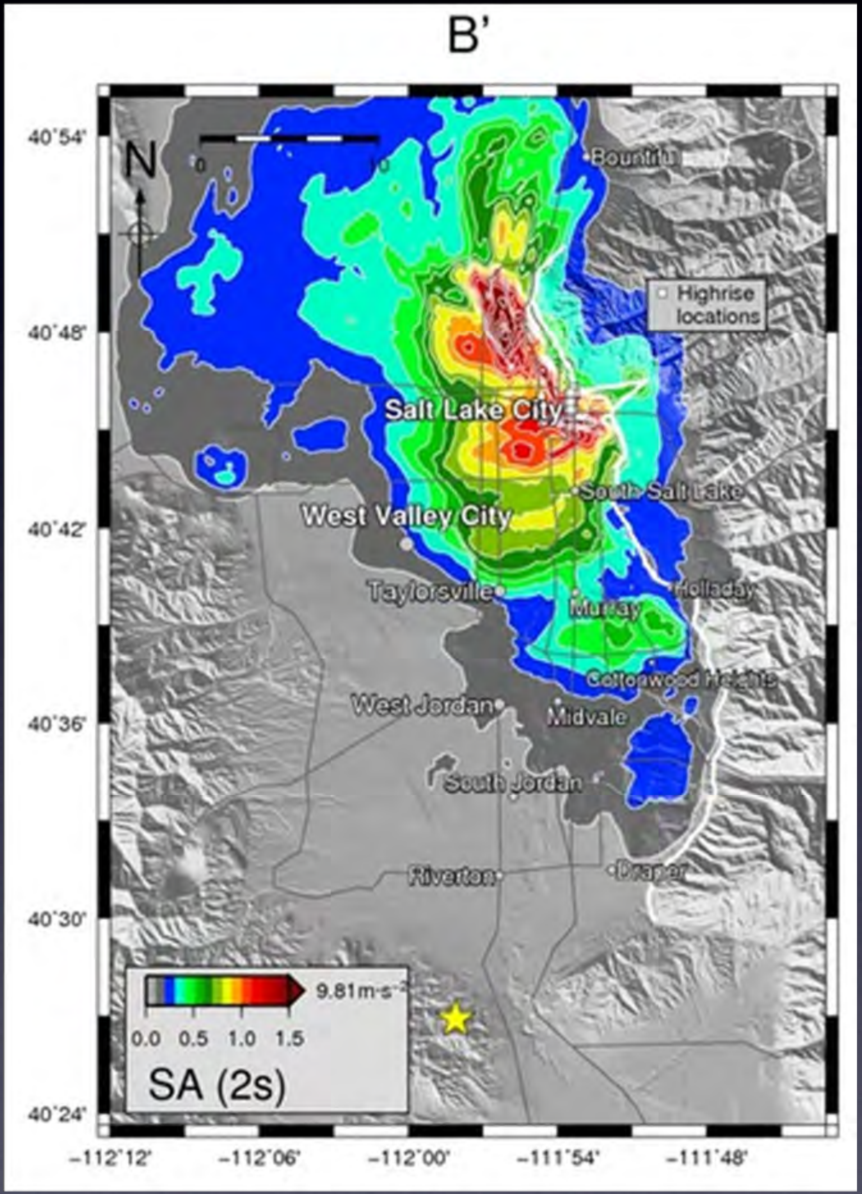


Spectral Accelerations at 2s (2s-SAs)

Scenario 5a

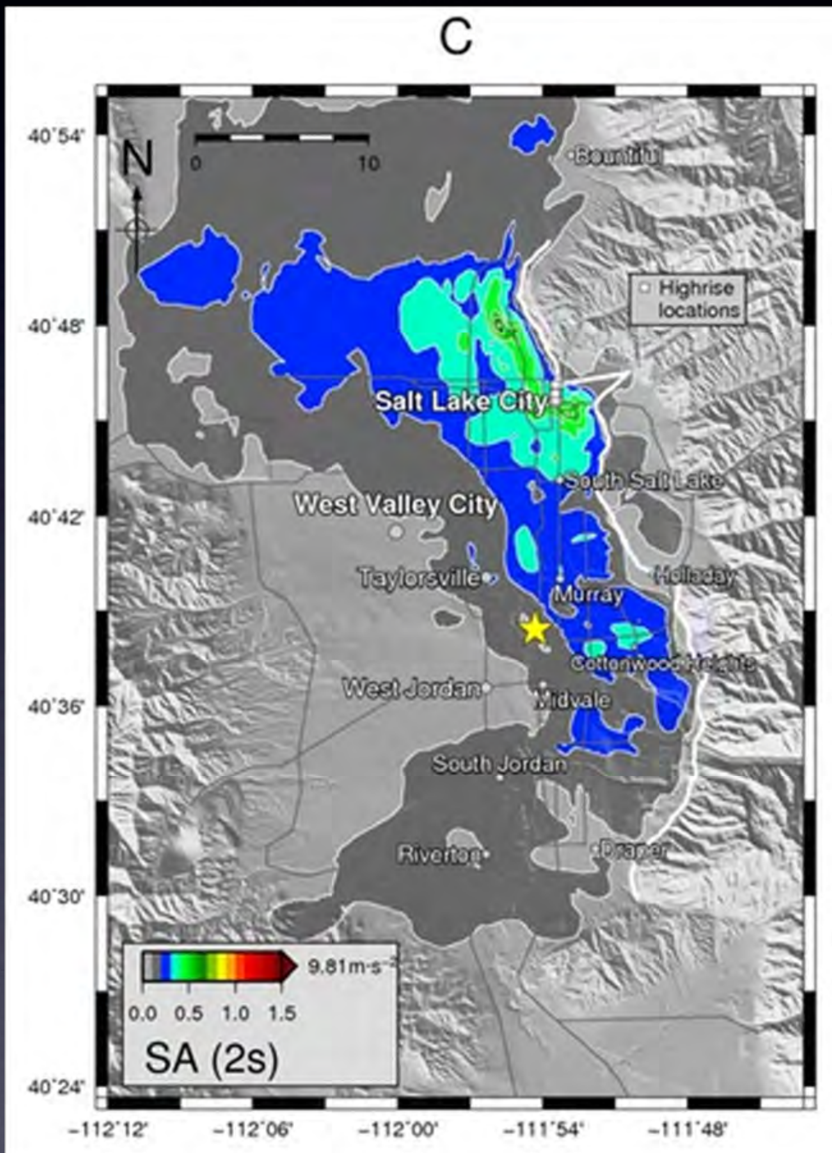


Scenario 5aM

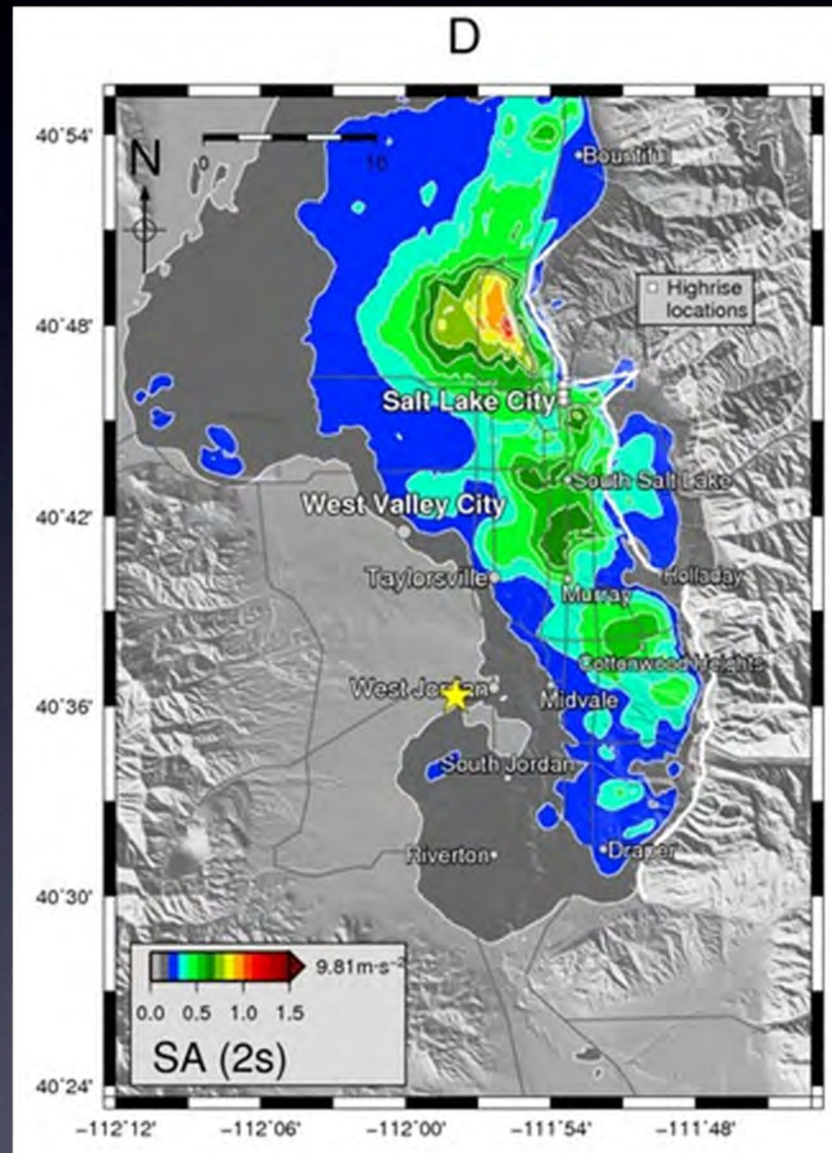


Spectral Accelerations at 2s (2s-SAs)

Scenario 3a



Scenario 6c



Spectral Accelerations at 3s (3s-SAs)

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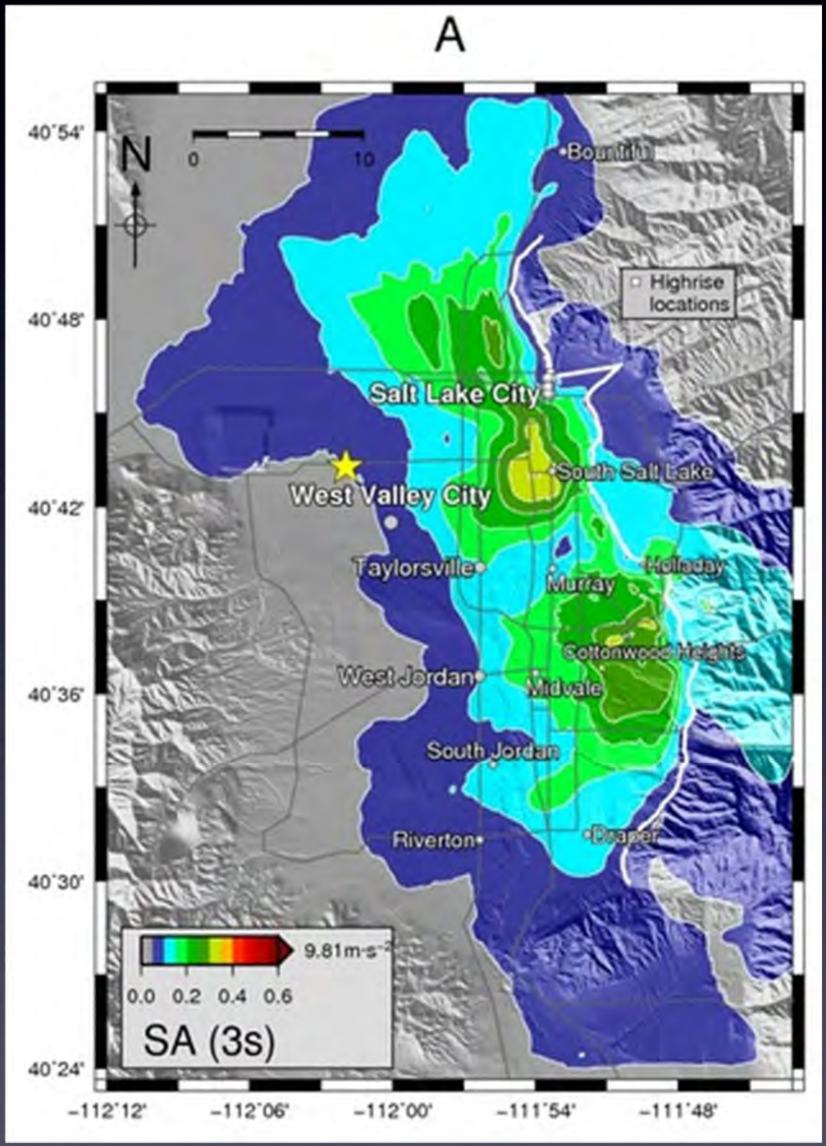
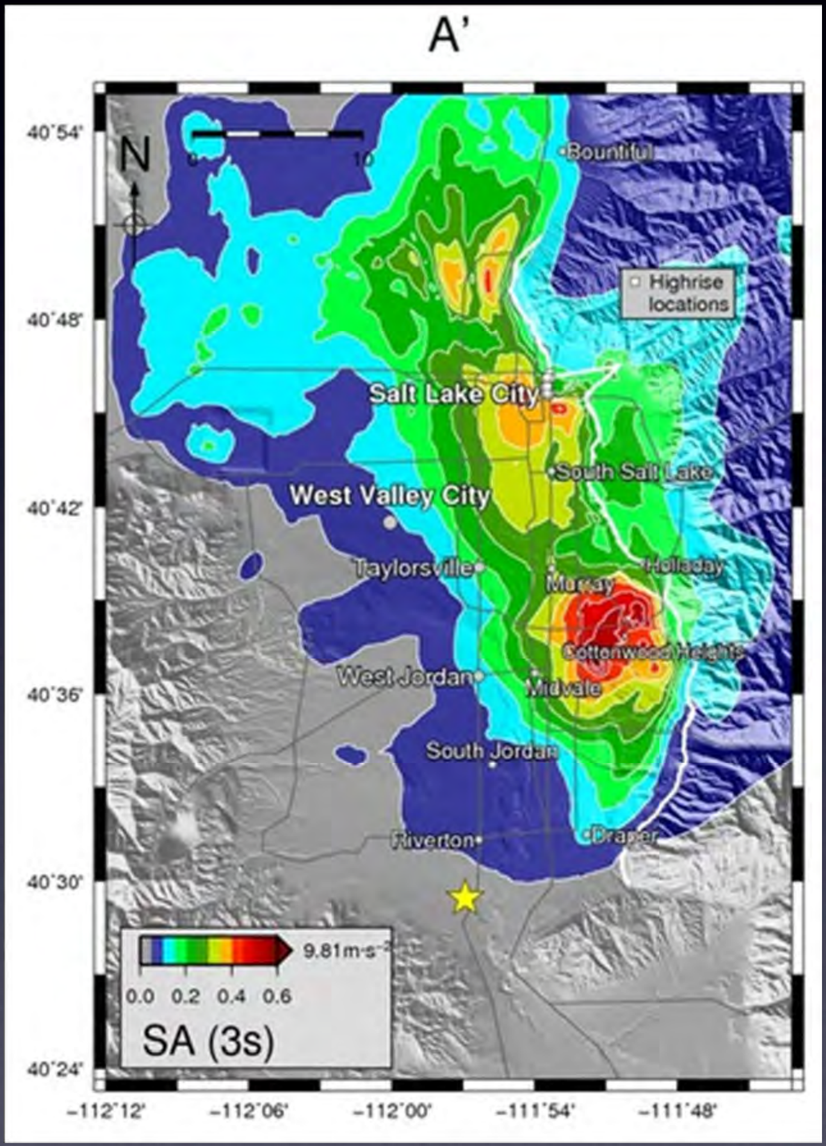


Scenario 2aM



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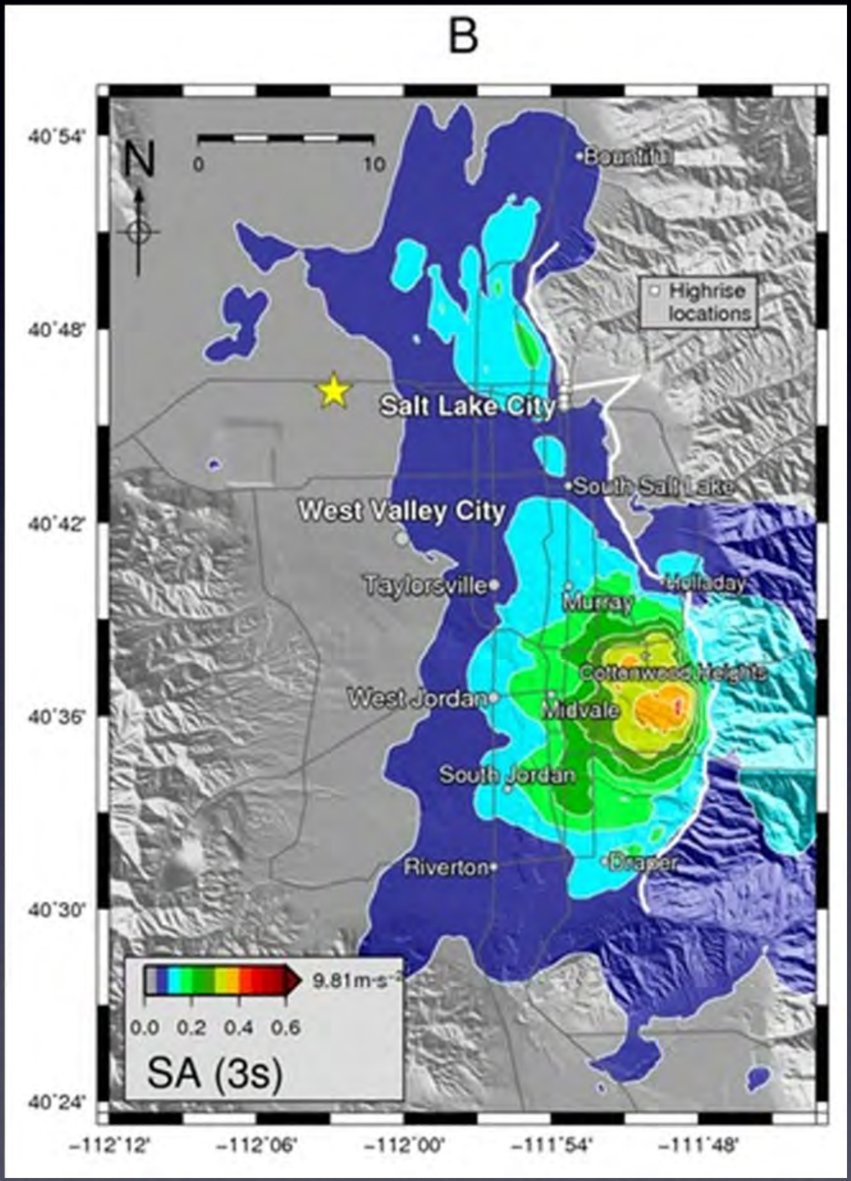

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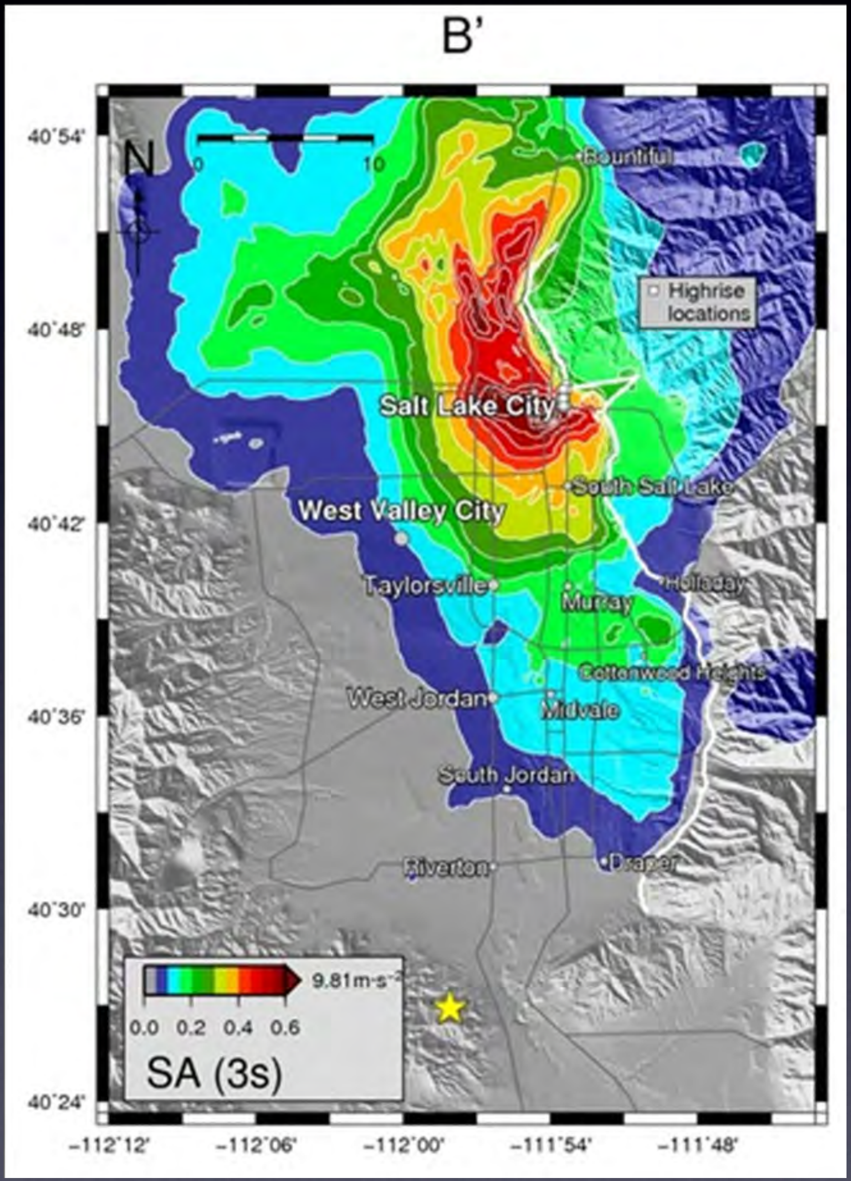

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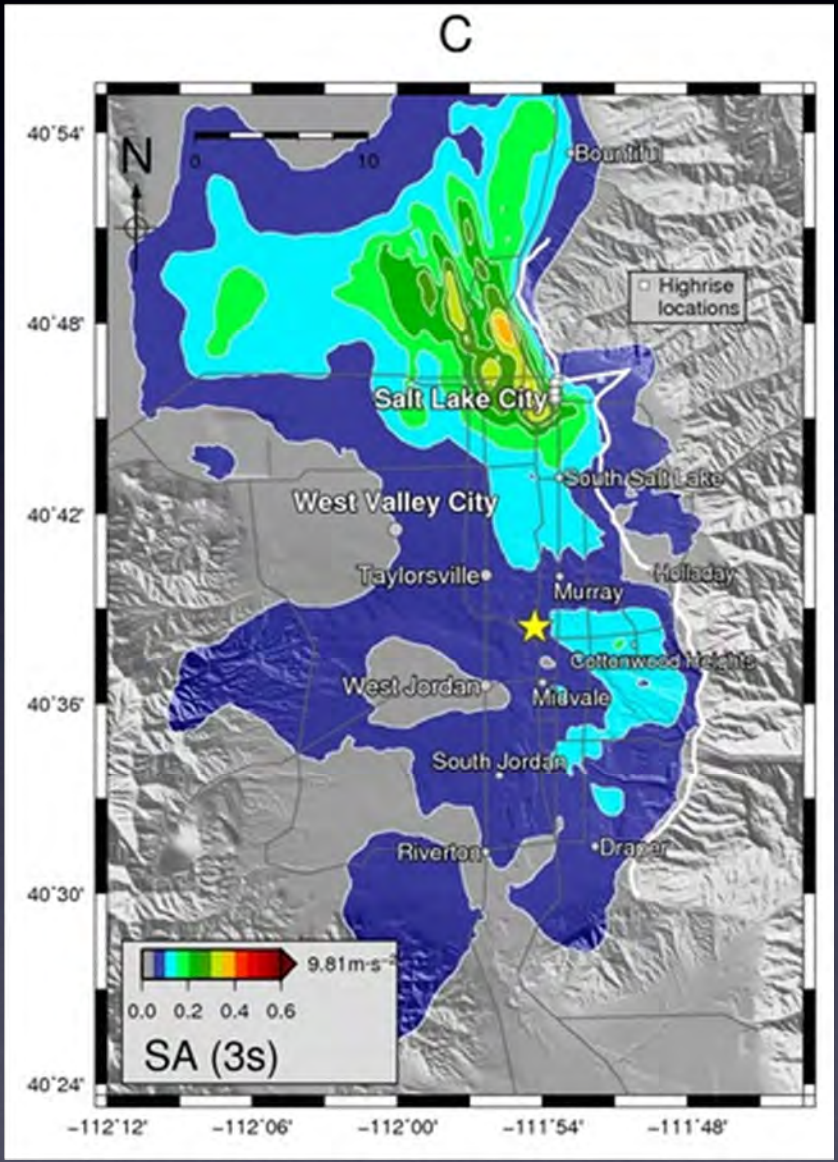
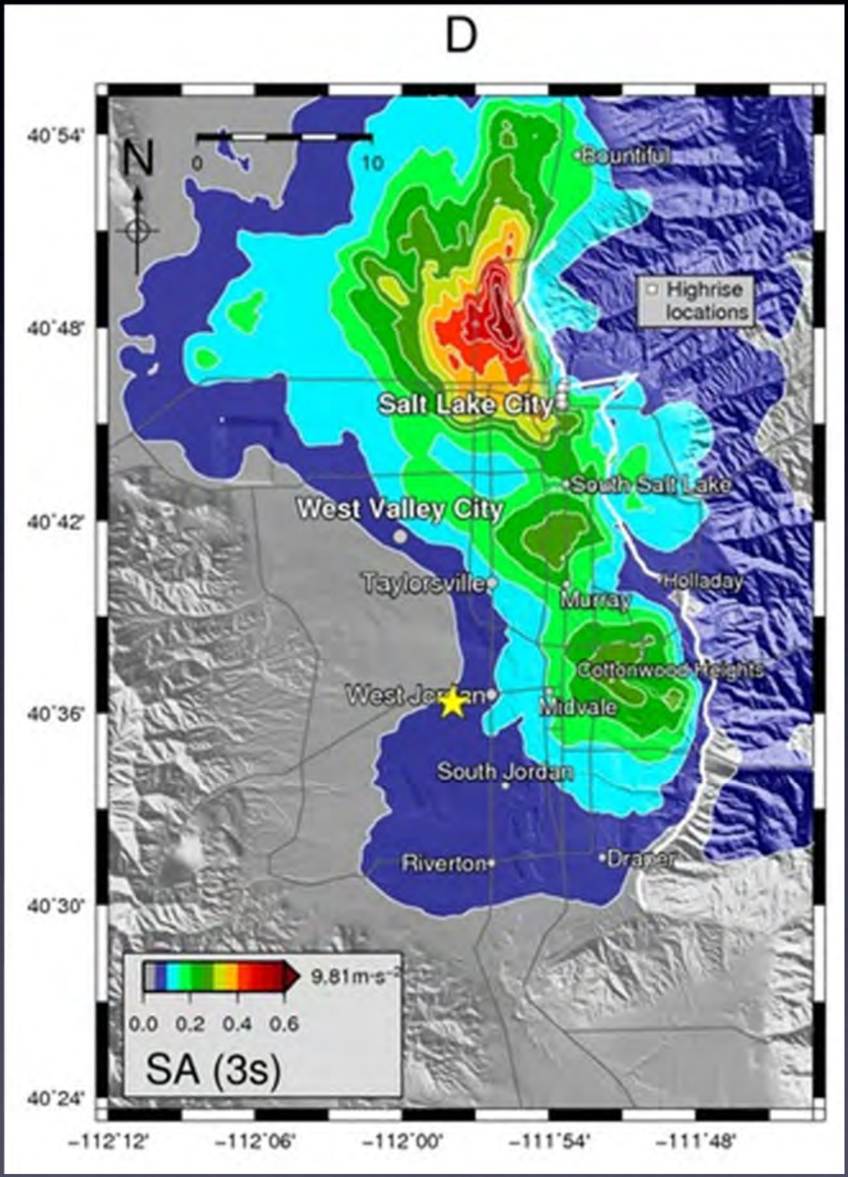
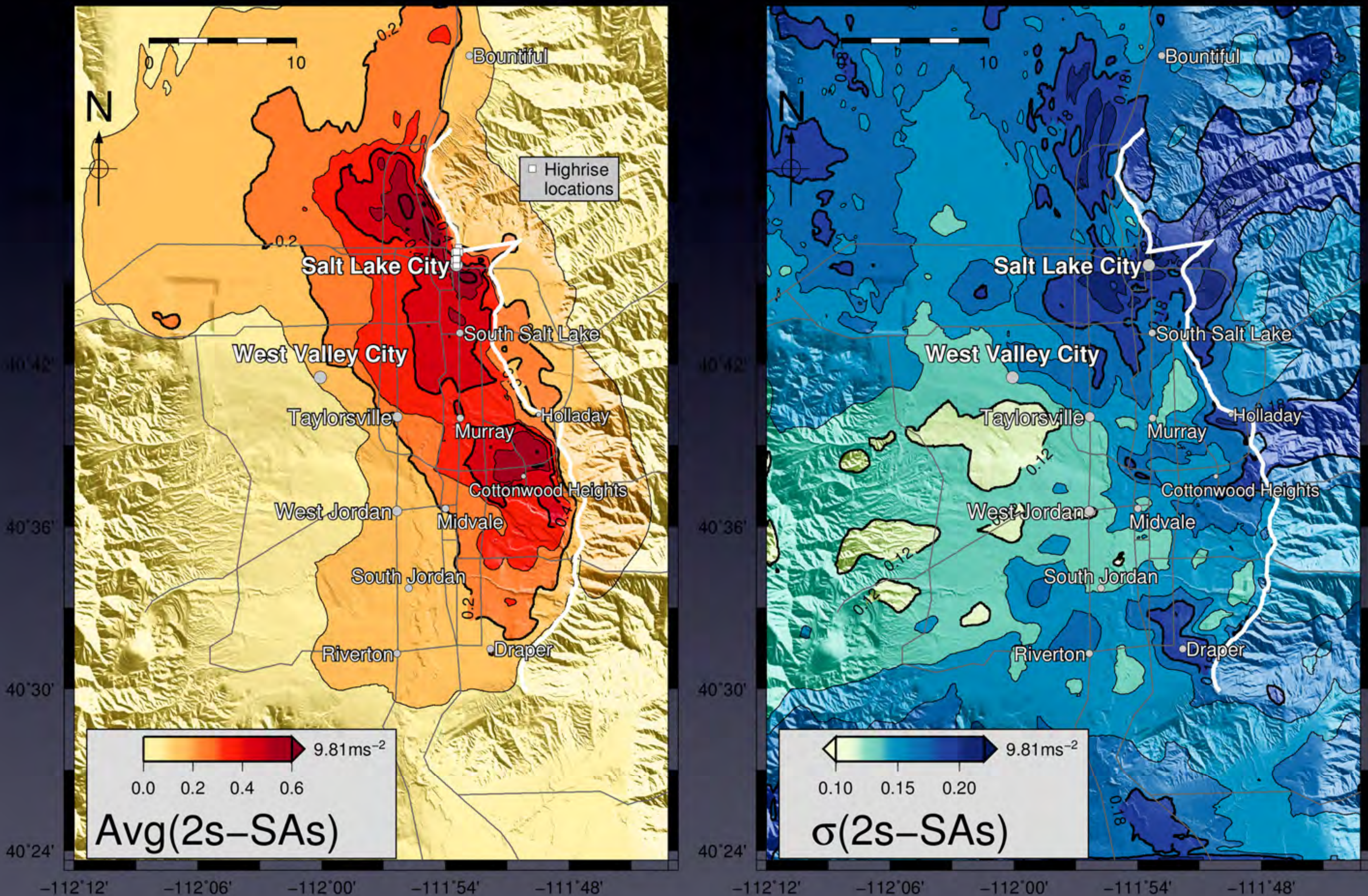


Scenario 6c

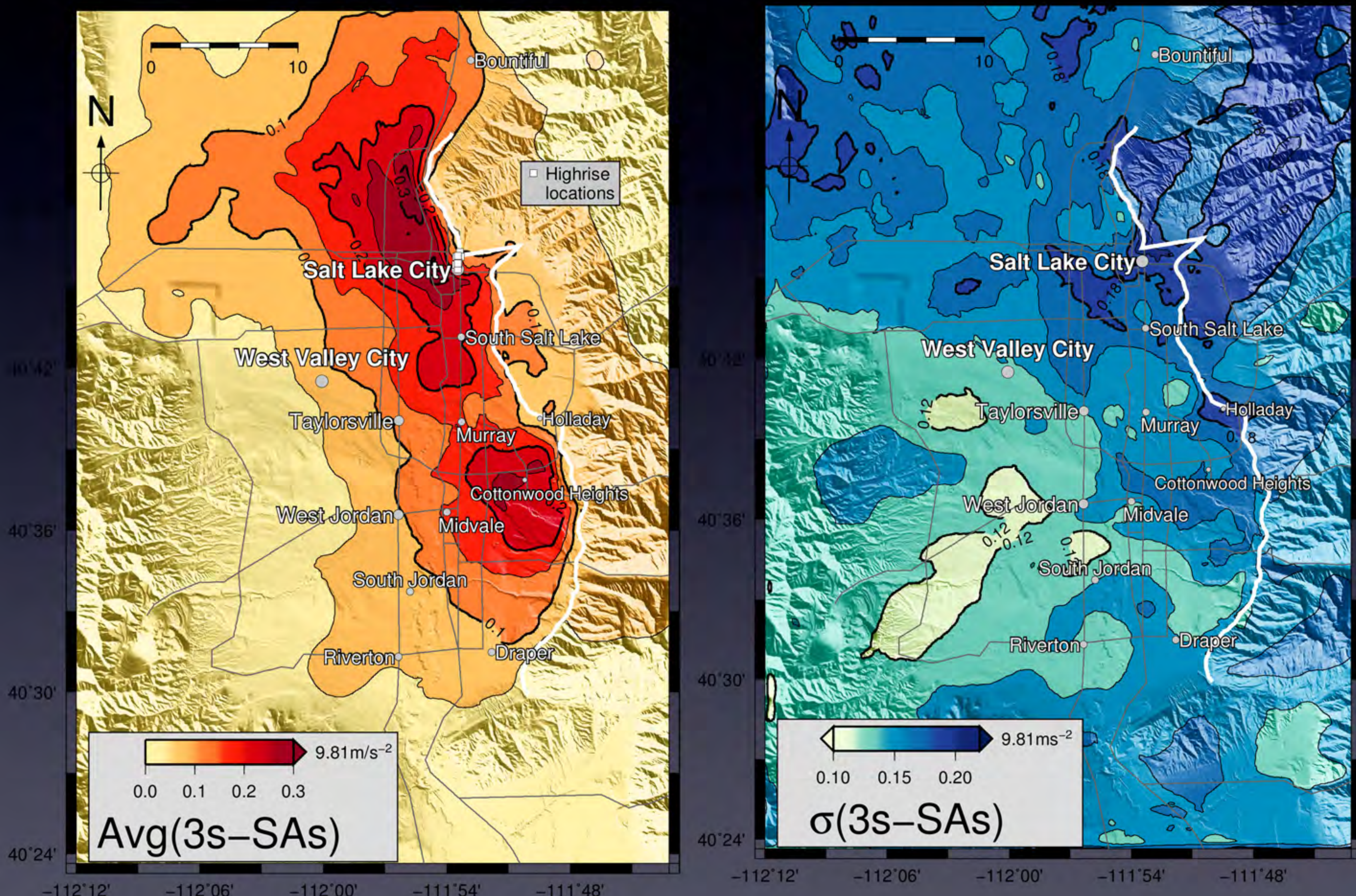


Average SAs



Highrise locations
Bountiful
Salt Lake City
South Salt Lake
West Valley City
Taylorsville
Holladay
Murray
Cottonwood Heights
West Jordan
Midvale
South Jordan
Riverton
Draper
N
0
10
0.2
0.4
9.81ms^{-2}
0.0 0.2 0.4 0.6
Avg(2s–SAs)
0.18
0.12
0.10 0.15 0.20
σ(2s–SAs)
40˚42'
40˚36'
40˚30'
40˚24'
−112˚12' −112˚06' −112˚00' −111˚54' −111˚48'

Average SAs



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0.0 0.1 0.2 0.3
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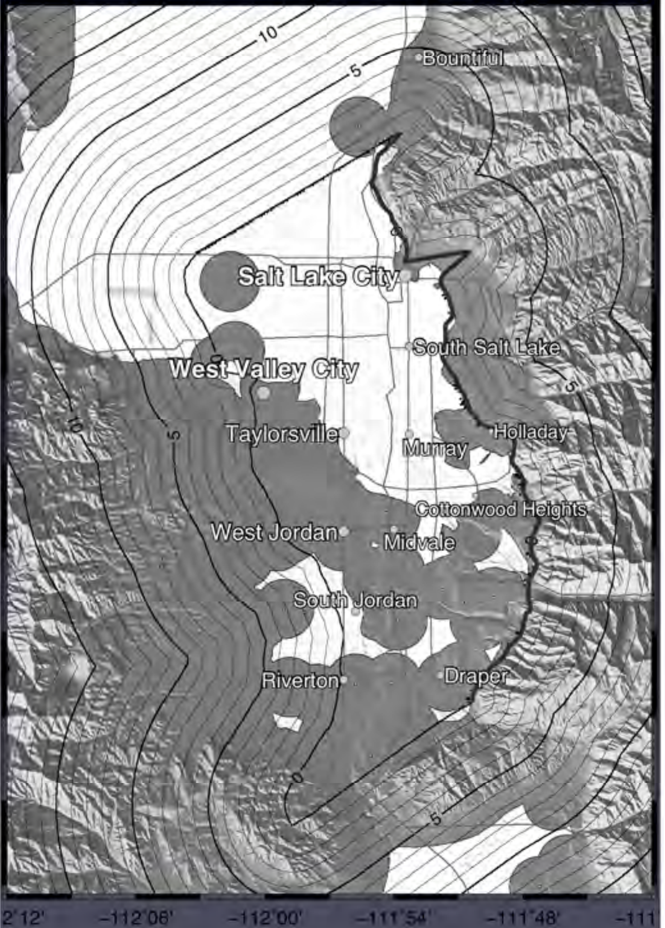
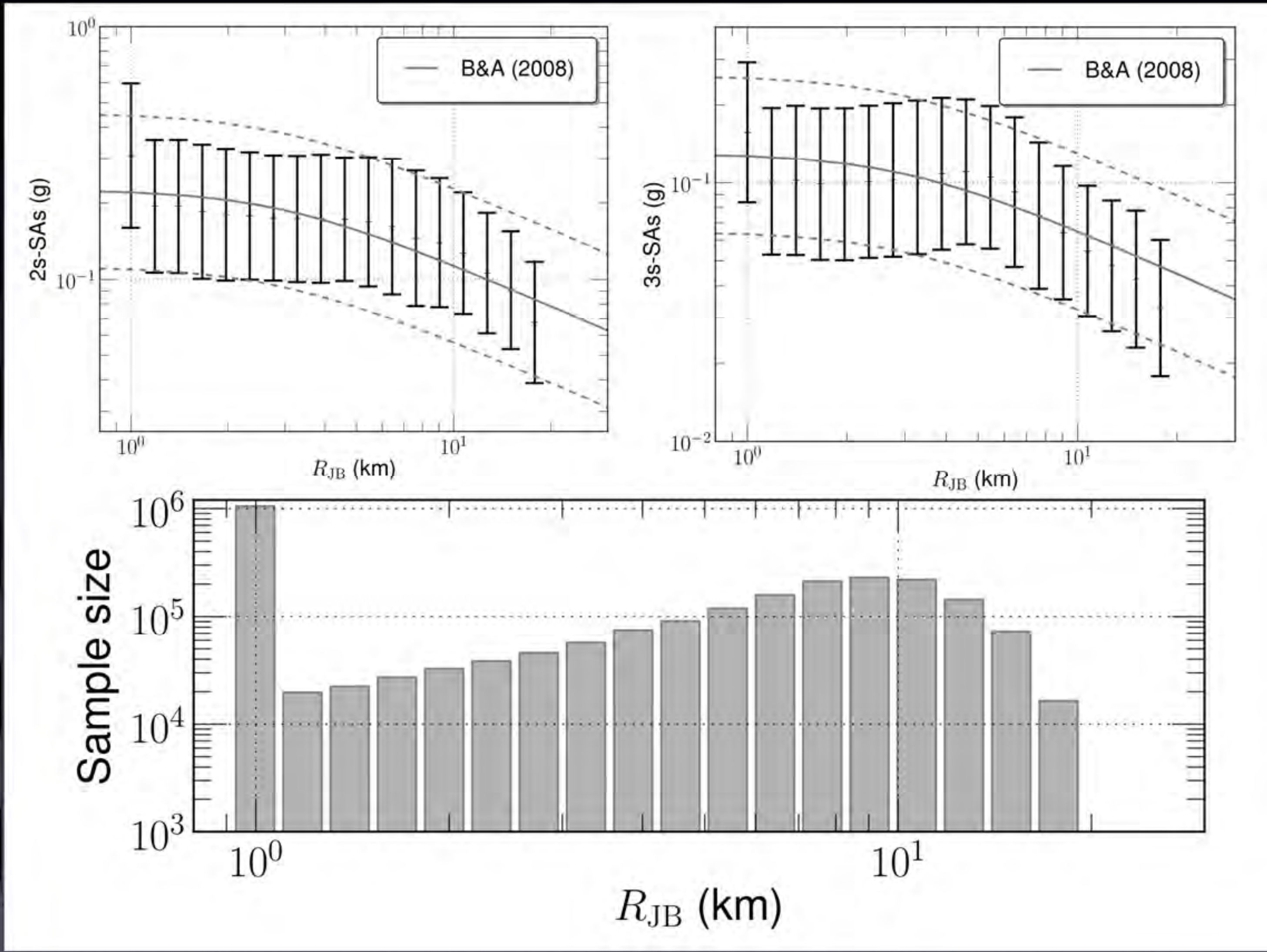
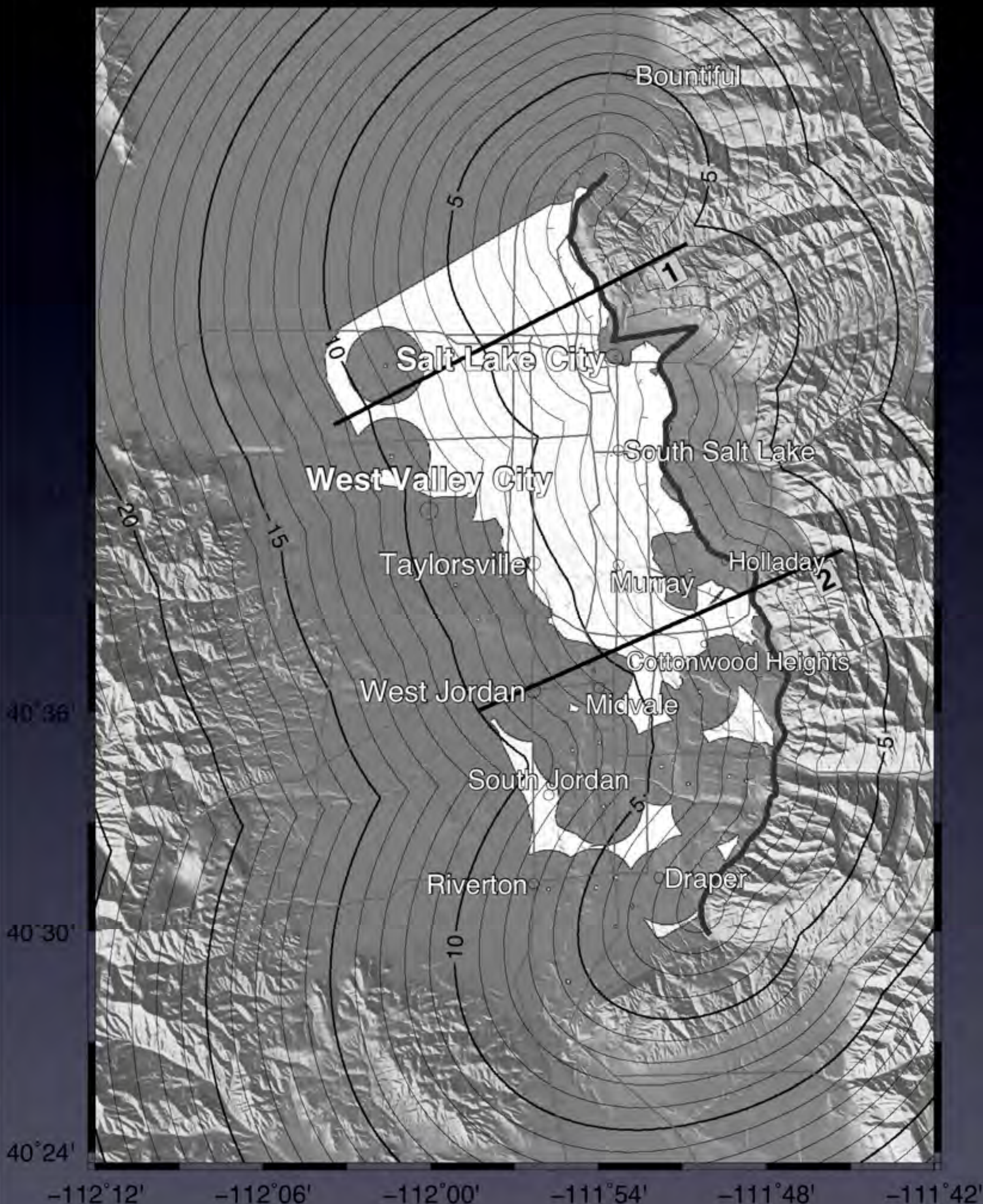
0.10 0.15 0.20
σ(3s–SAs)

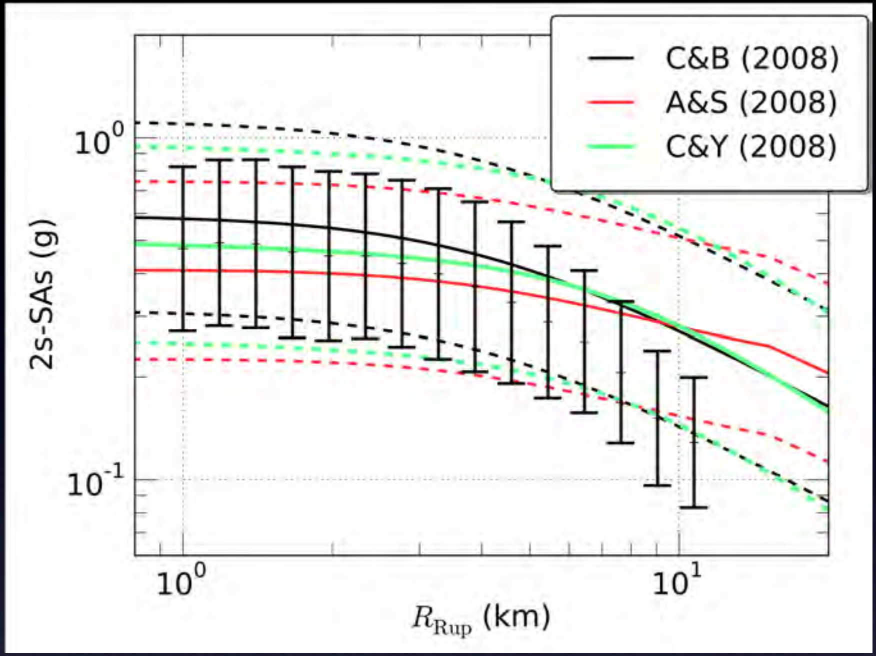
Comparison to NGA(2s-SAs)
200 m/s < vs < 300 m/s

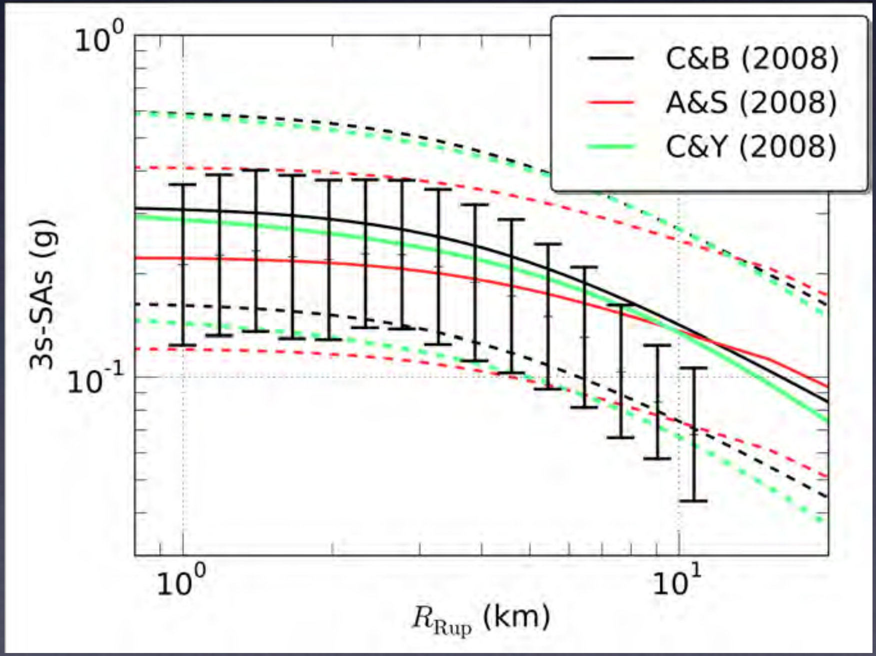




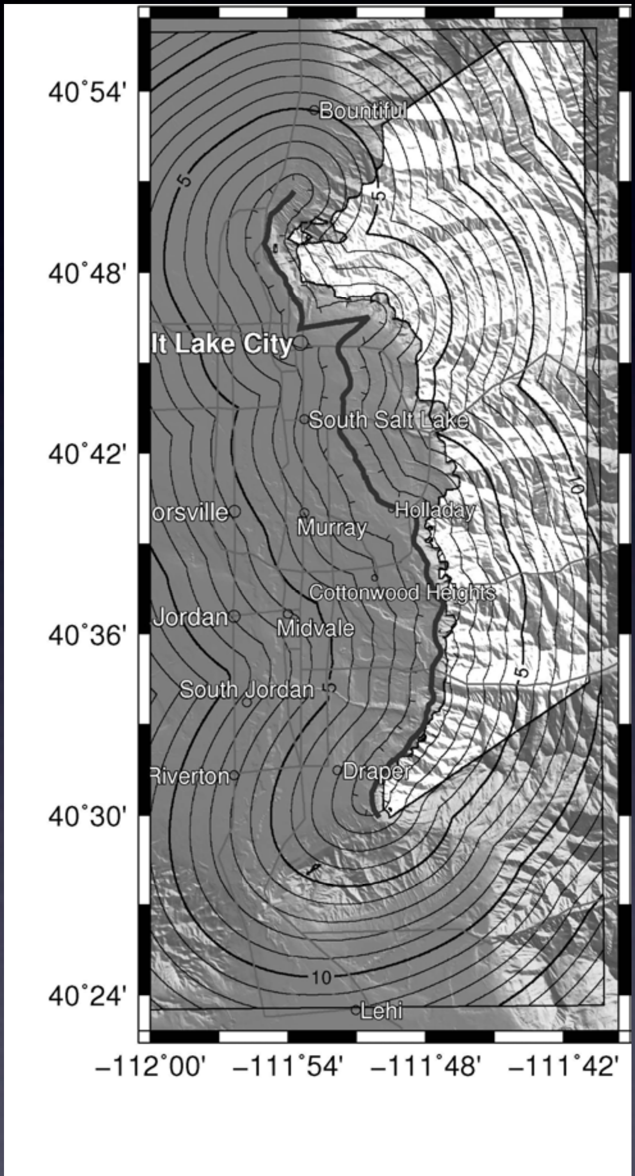
Comparison to NGA (2s-Sas, 3s-SAs)

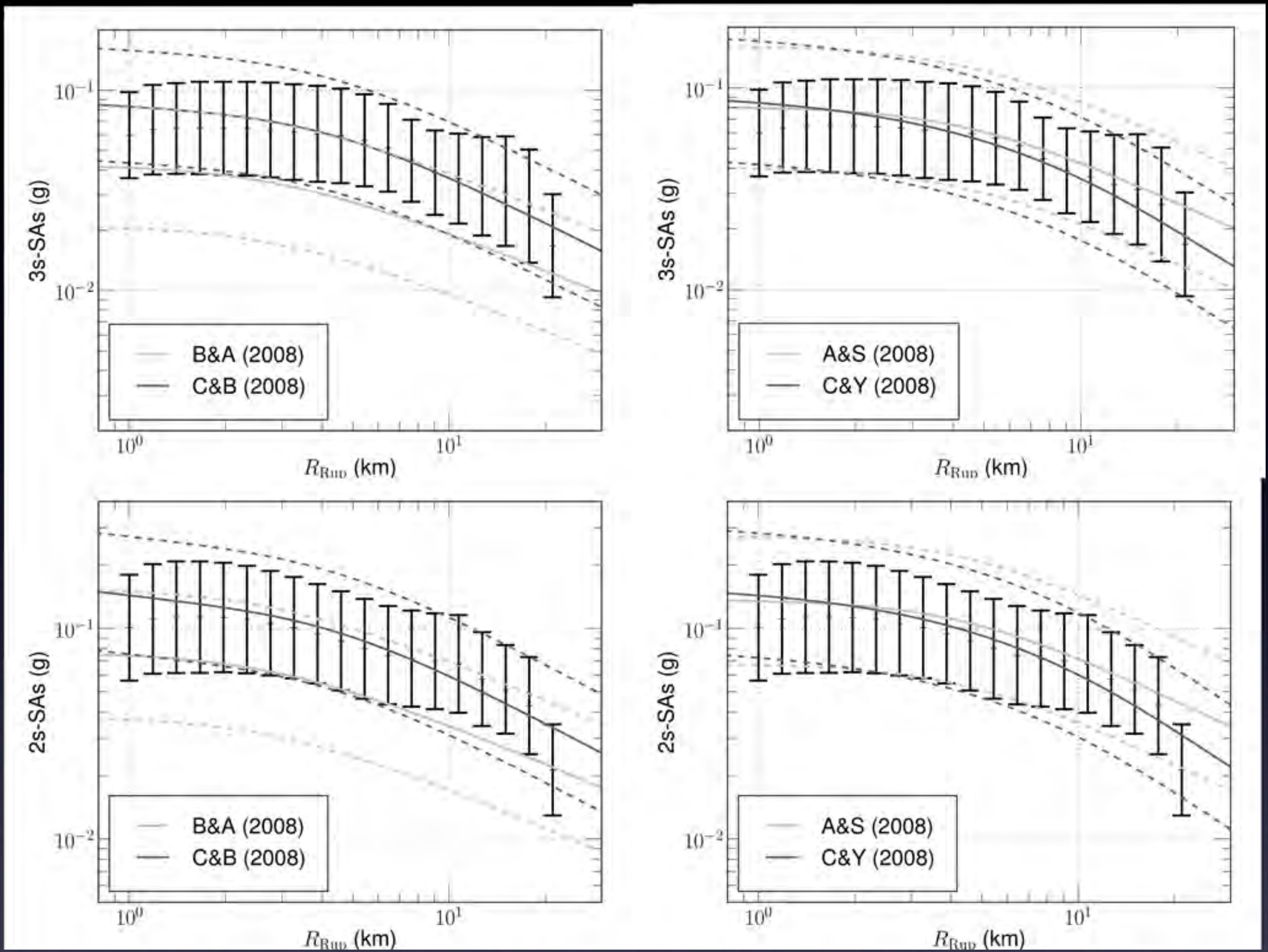


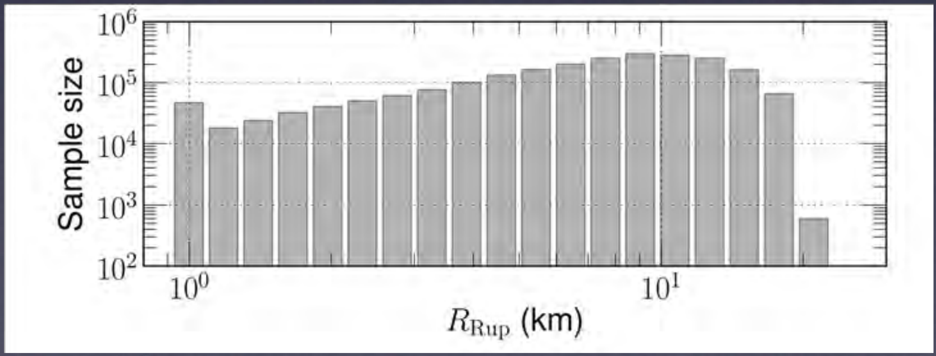




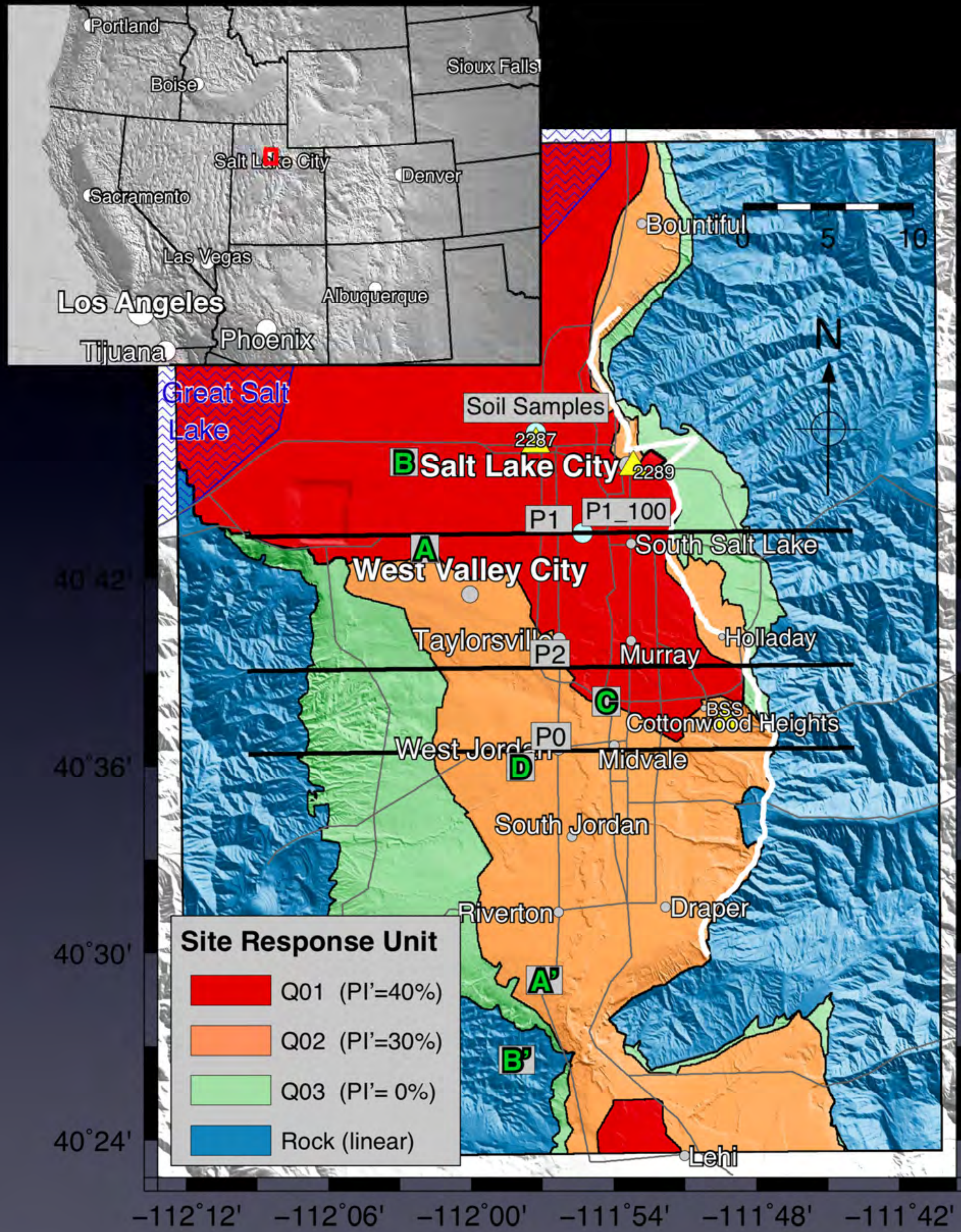
Comparison to NGA (2s-Sas, 3s-SAs) rock sites



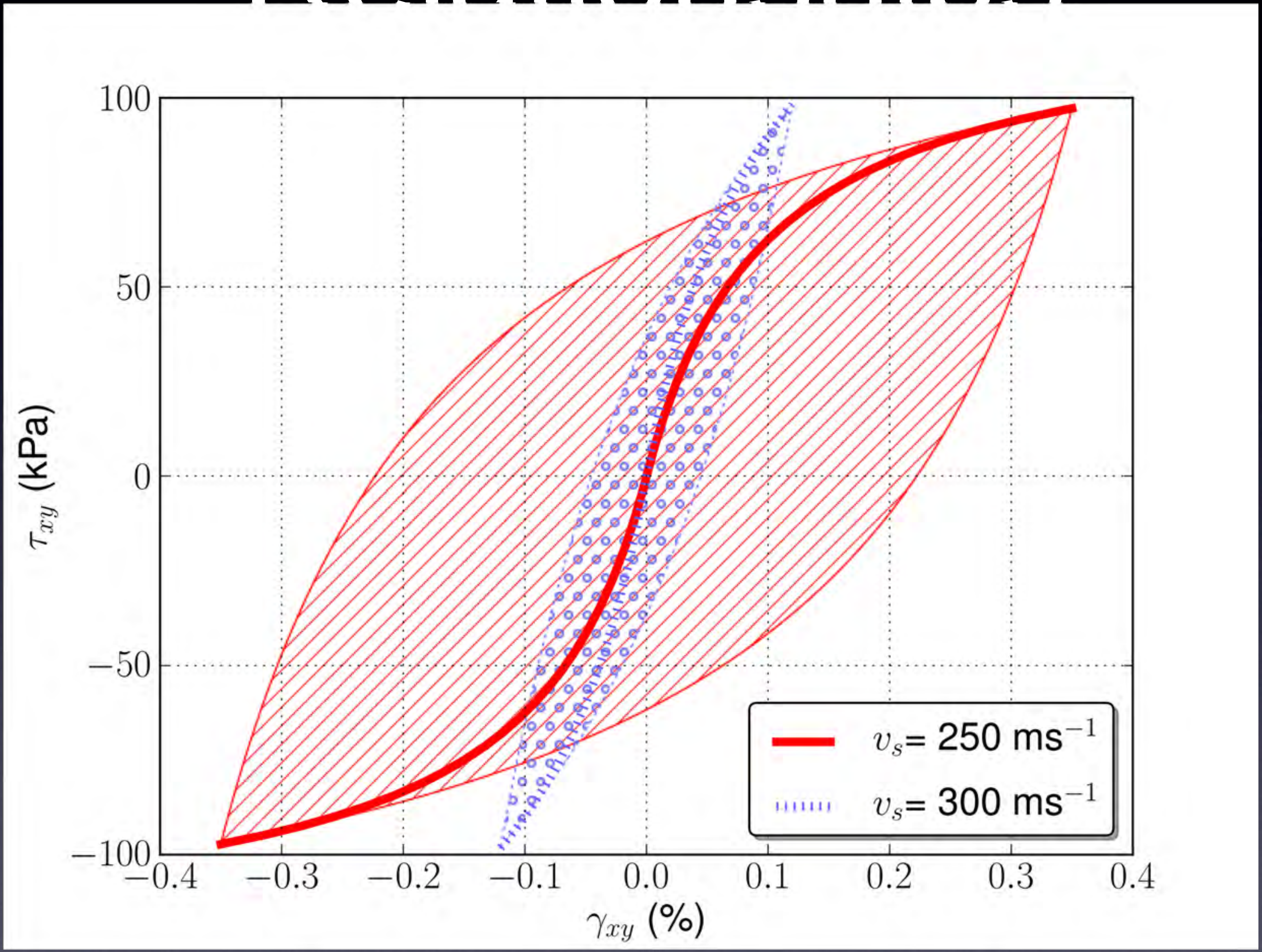




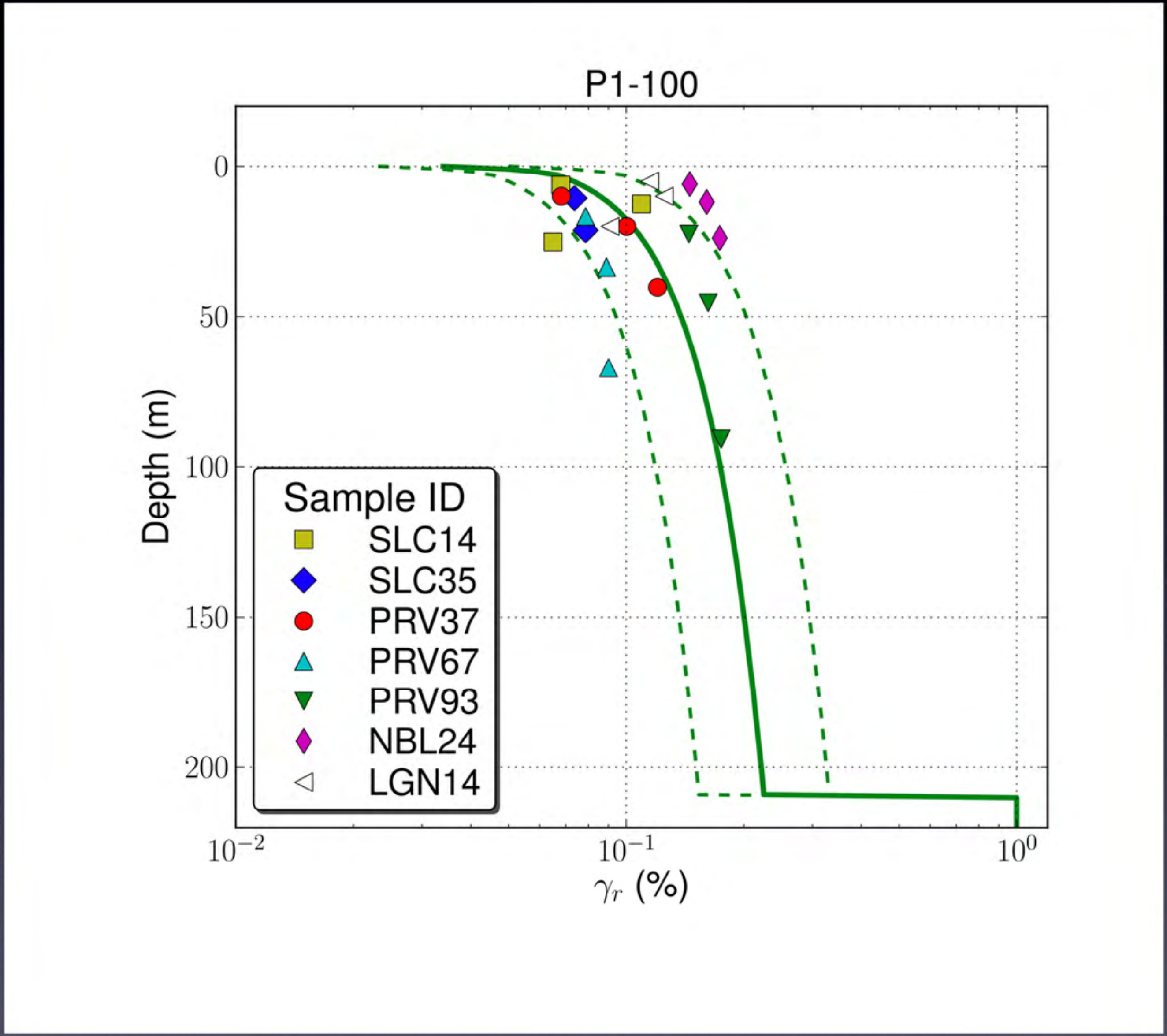
Nonlinear Soil Response



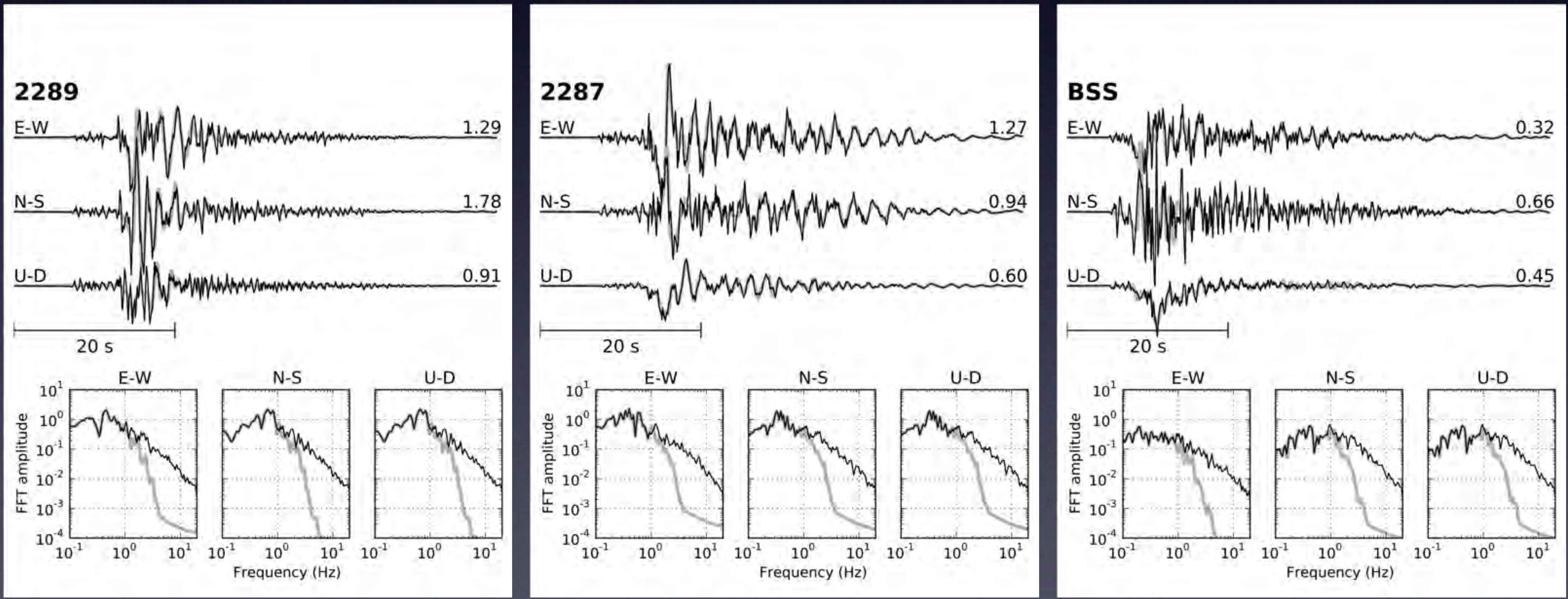
Stress-Strain Relationships



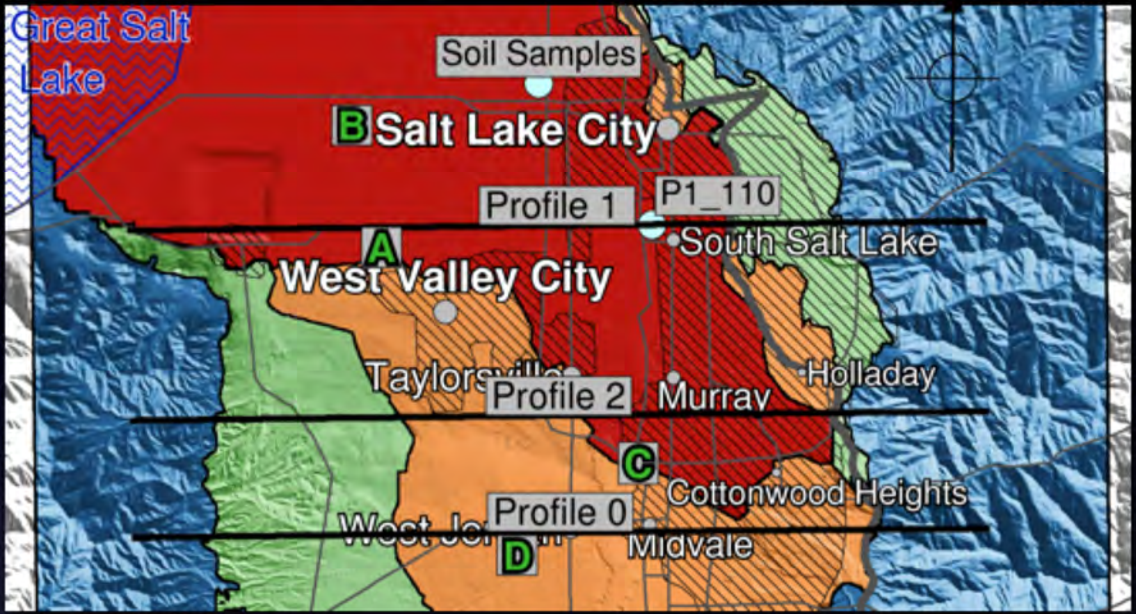
Reference Strain



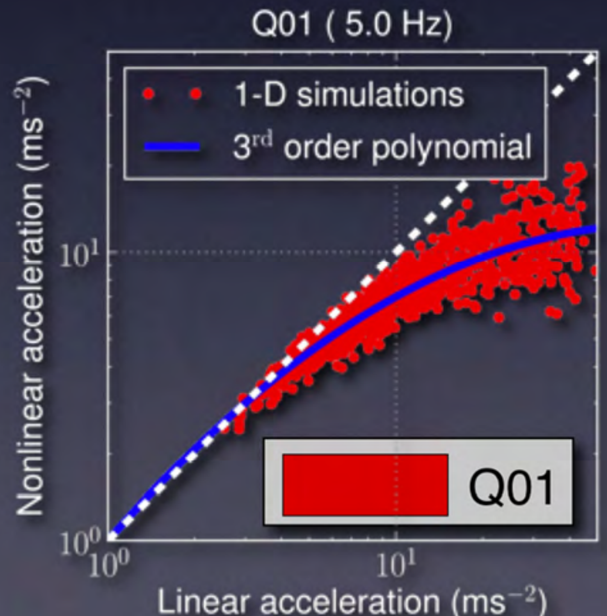
Example LF vs BB Synthetics



Correction Factors for BB SAs



- Definition of amplitude-and site-dependent correction factors
- Coefficients of 3rd order polynomial are determined for each SRU and frequency
- L2 norm using ~2,500 NL 1-D simulations



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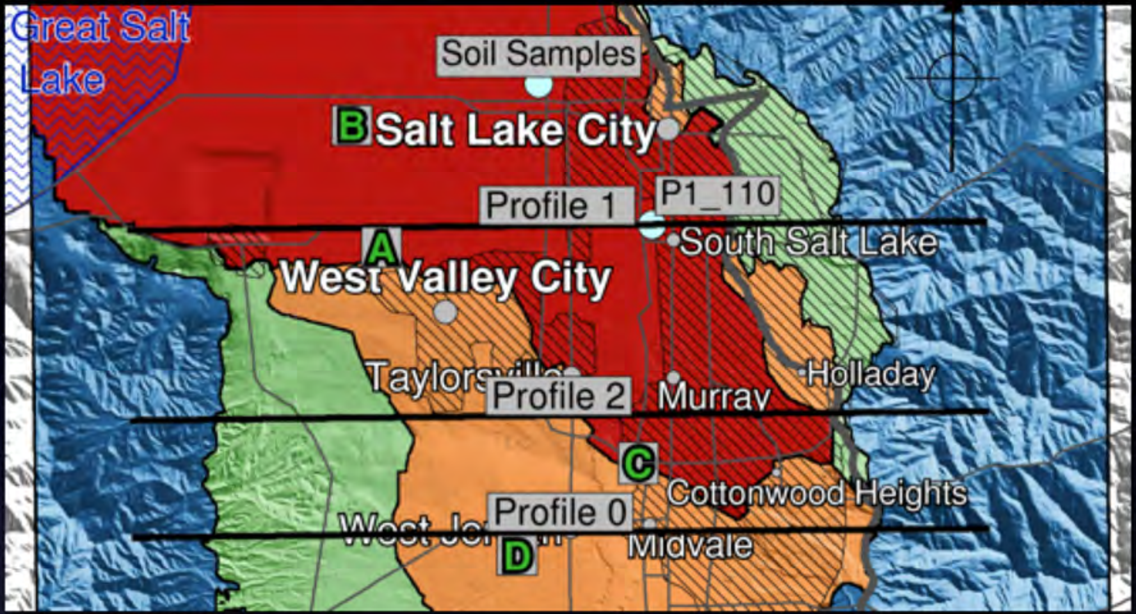

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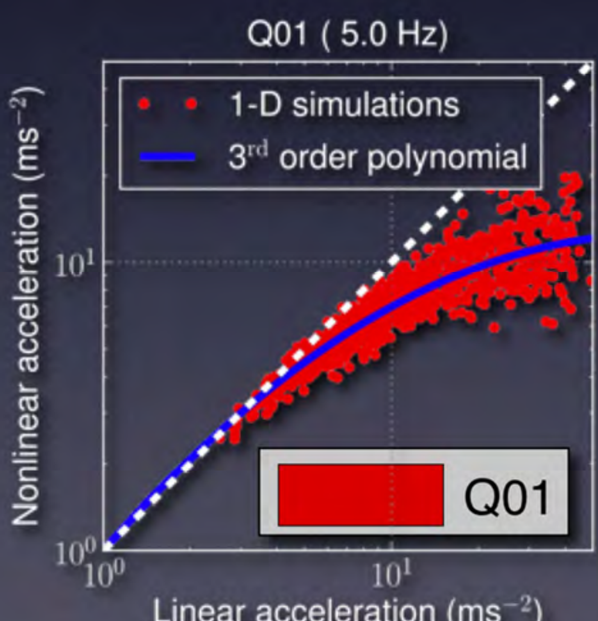

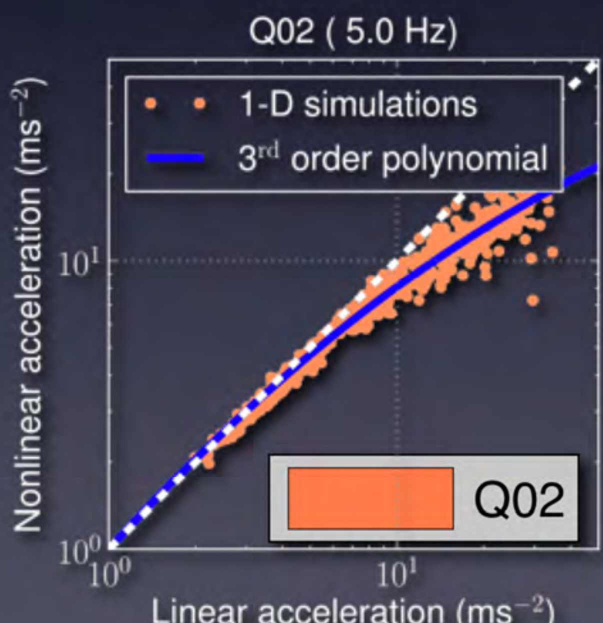

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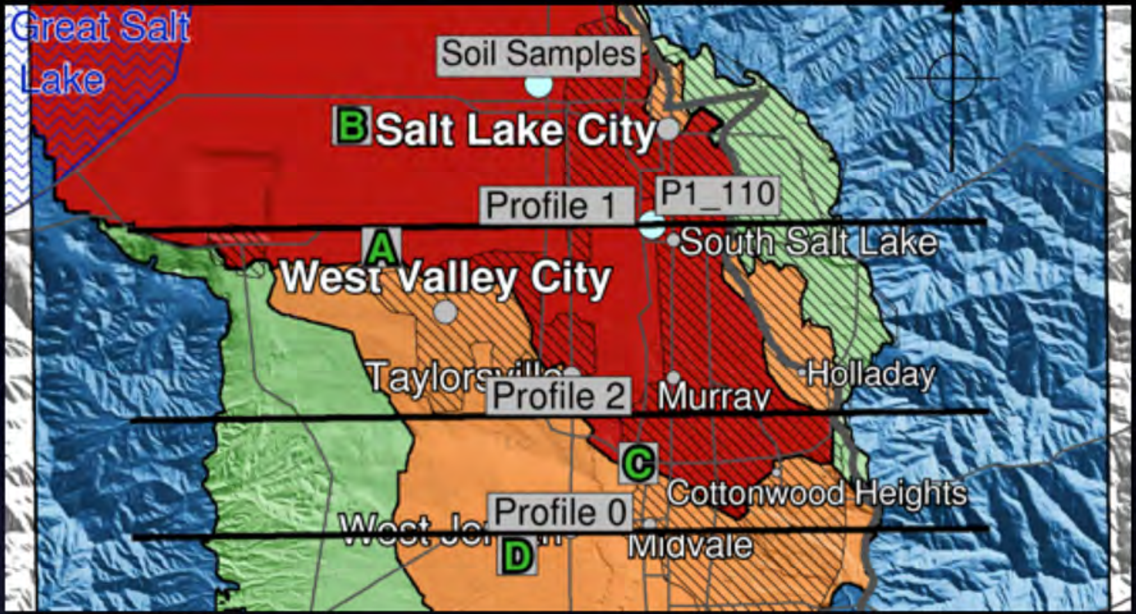

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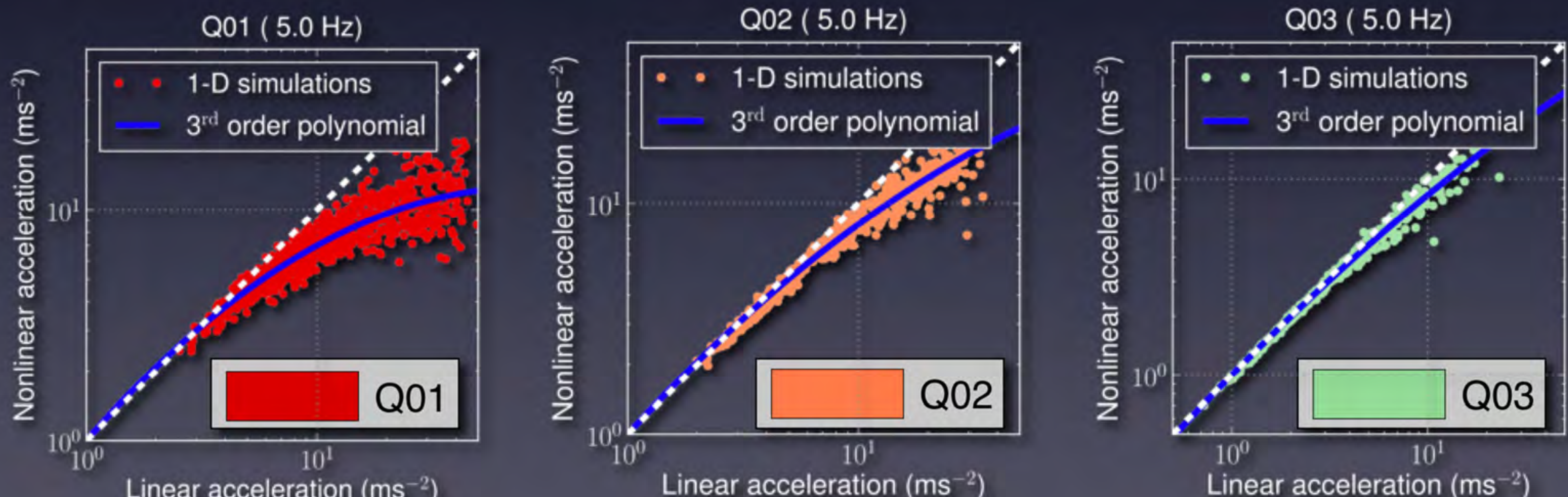
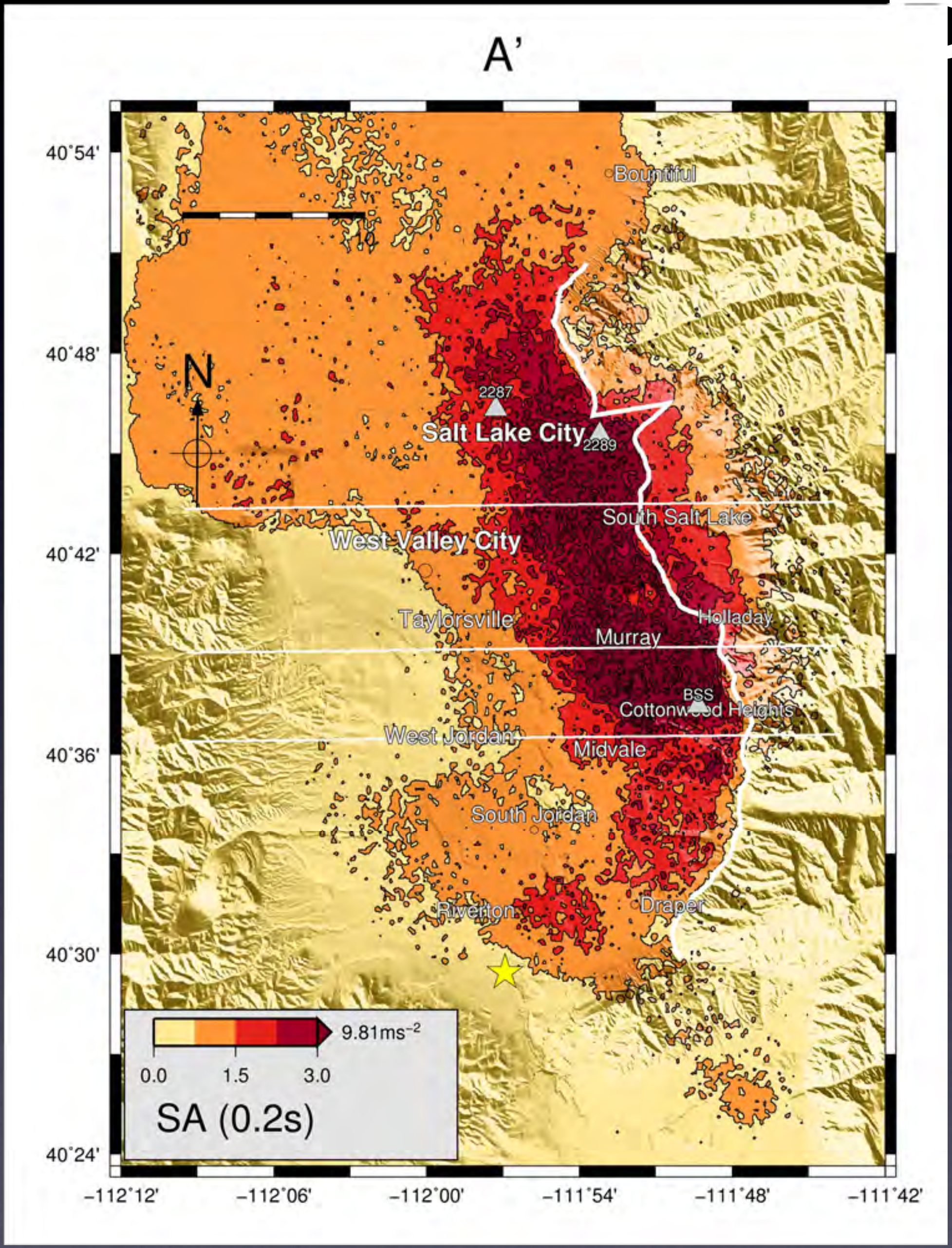
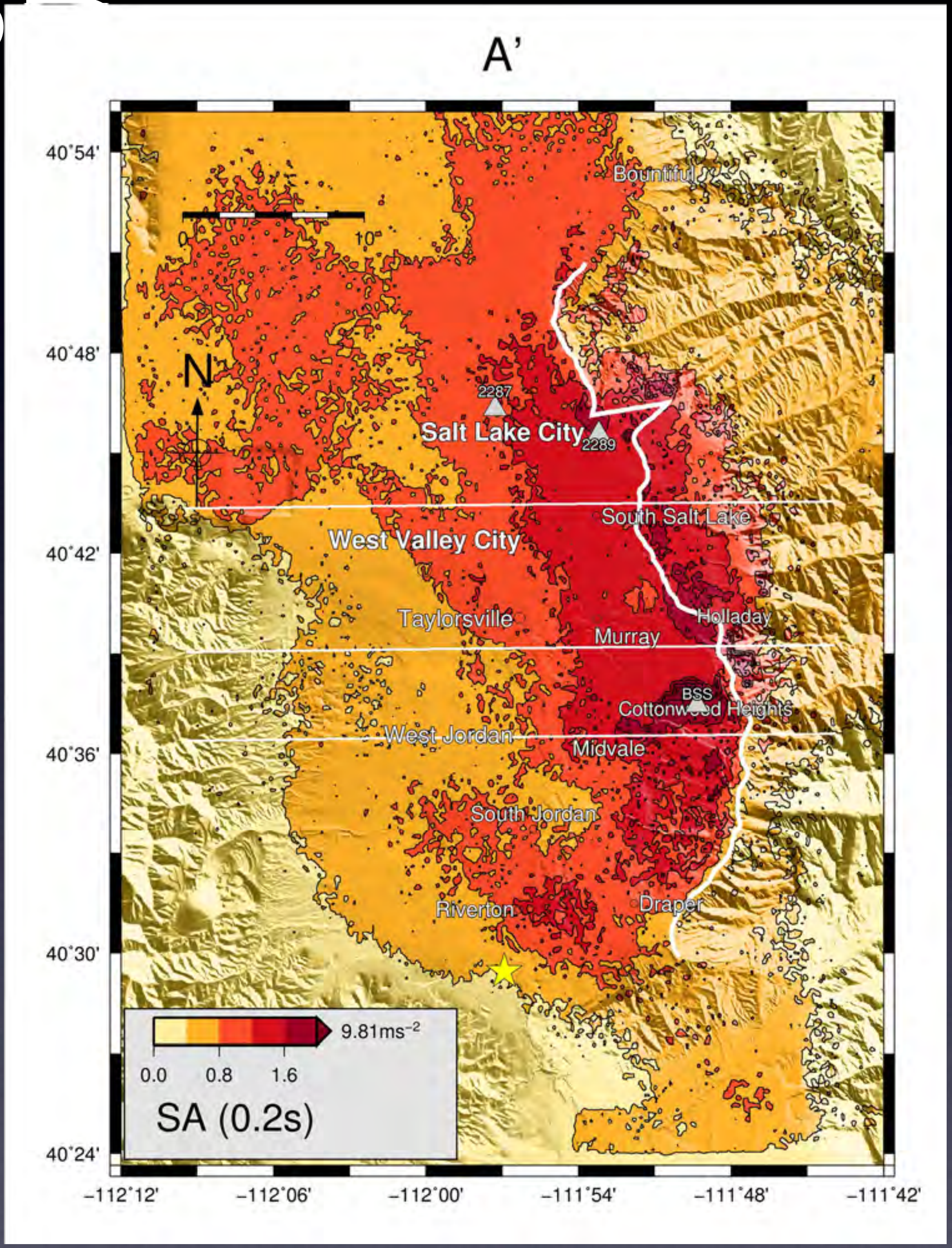
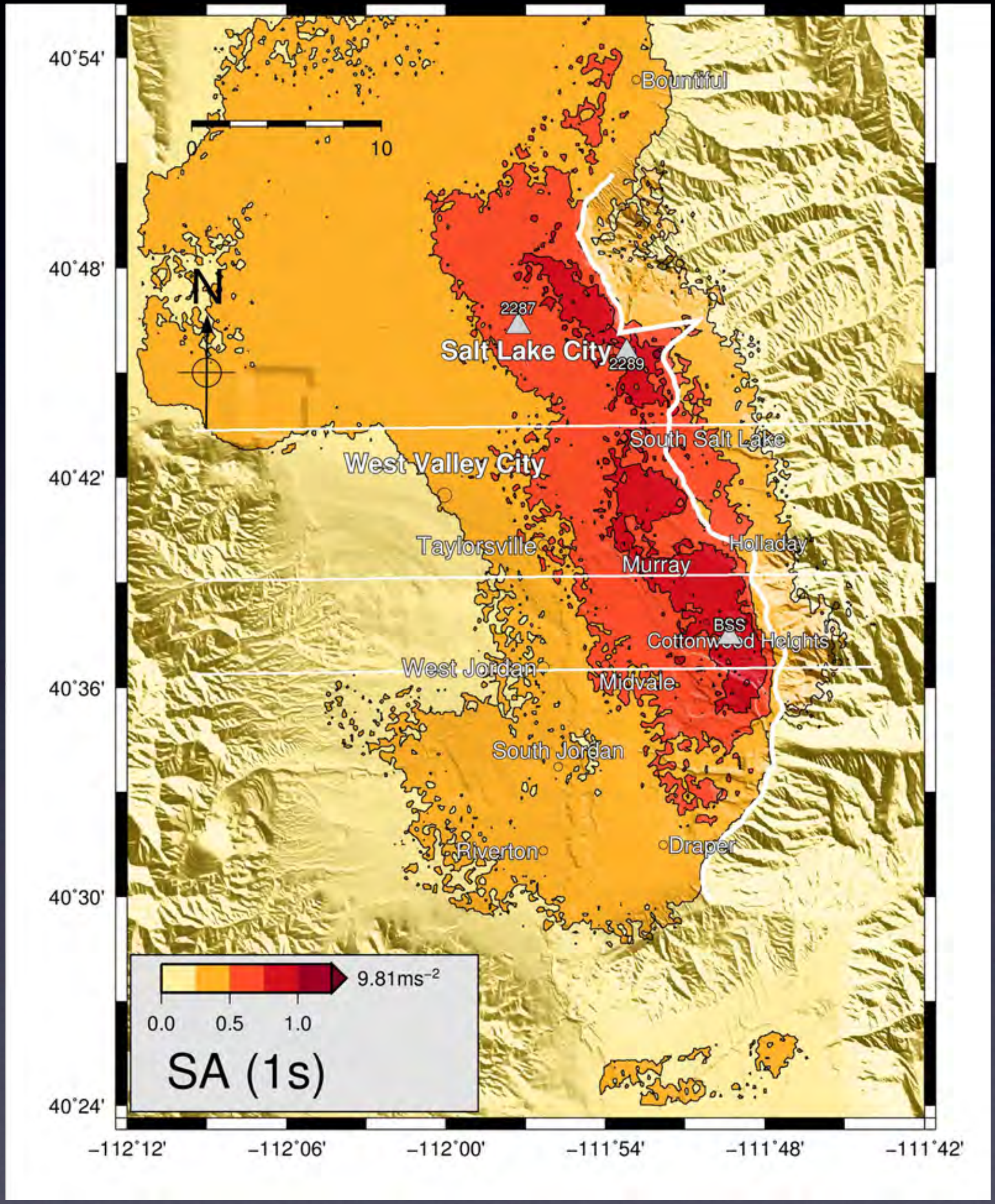


Linear vs Nonlinear BB

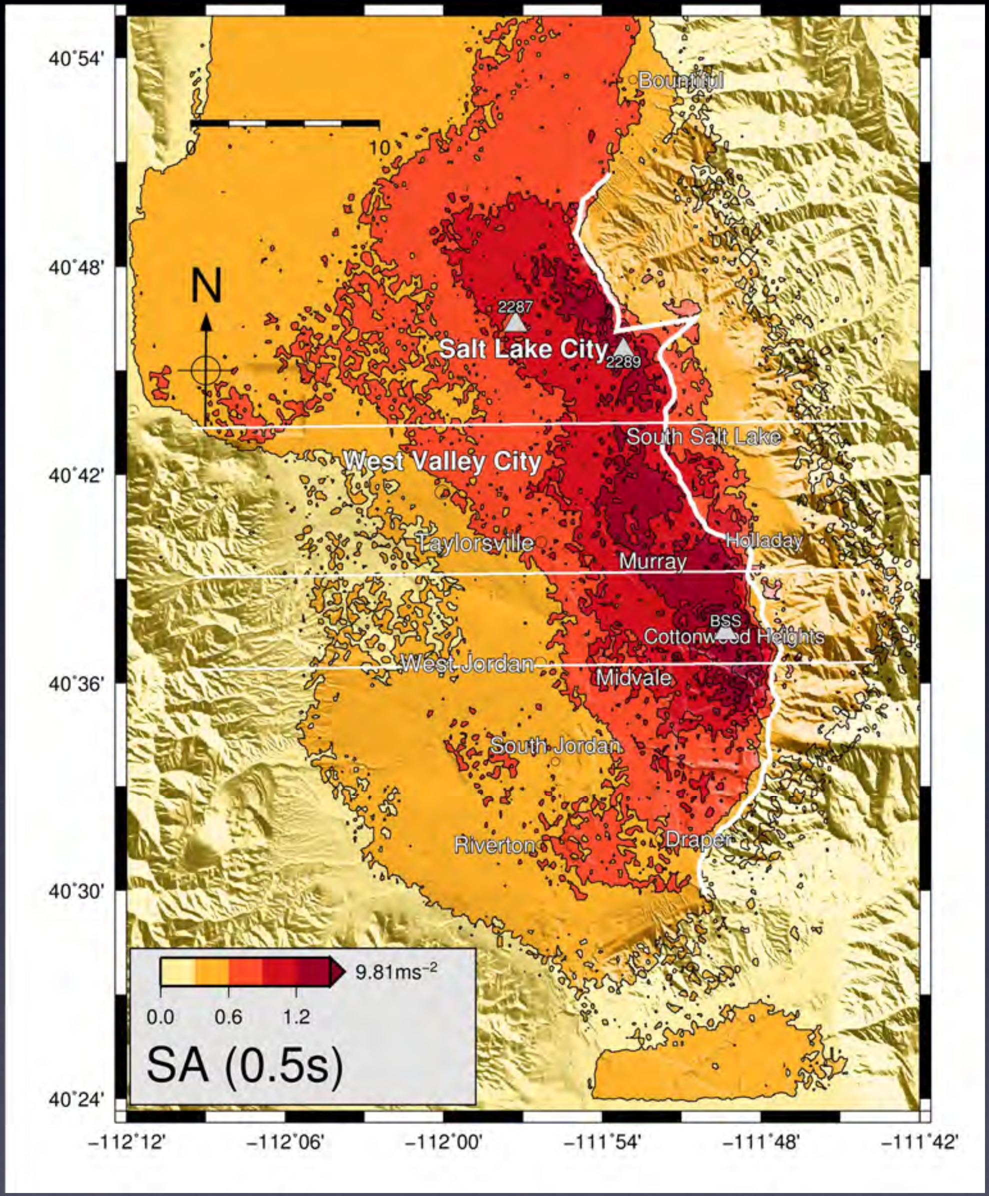




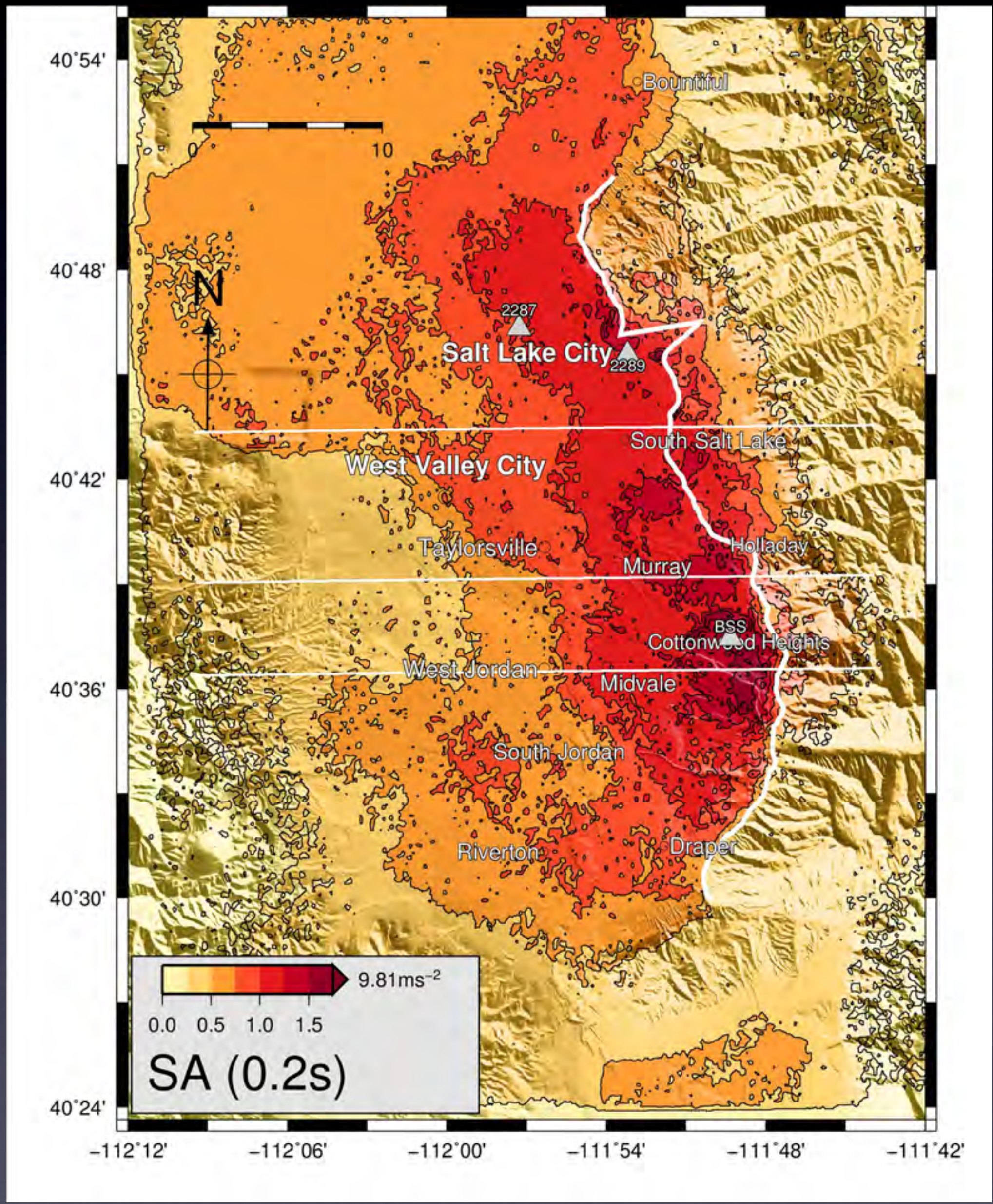
Ensemble SA(1s)



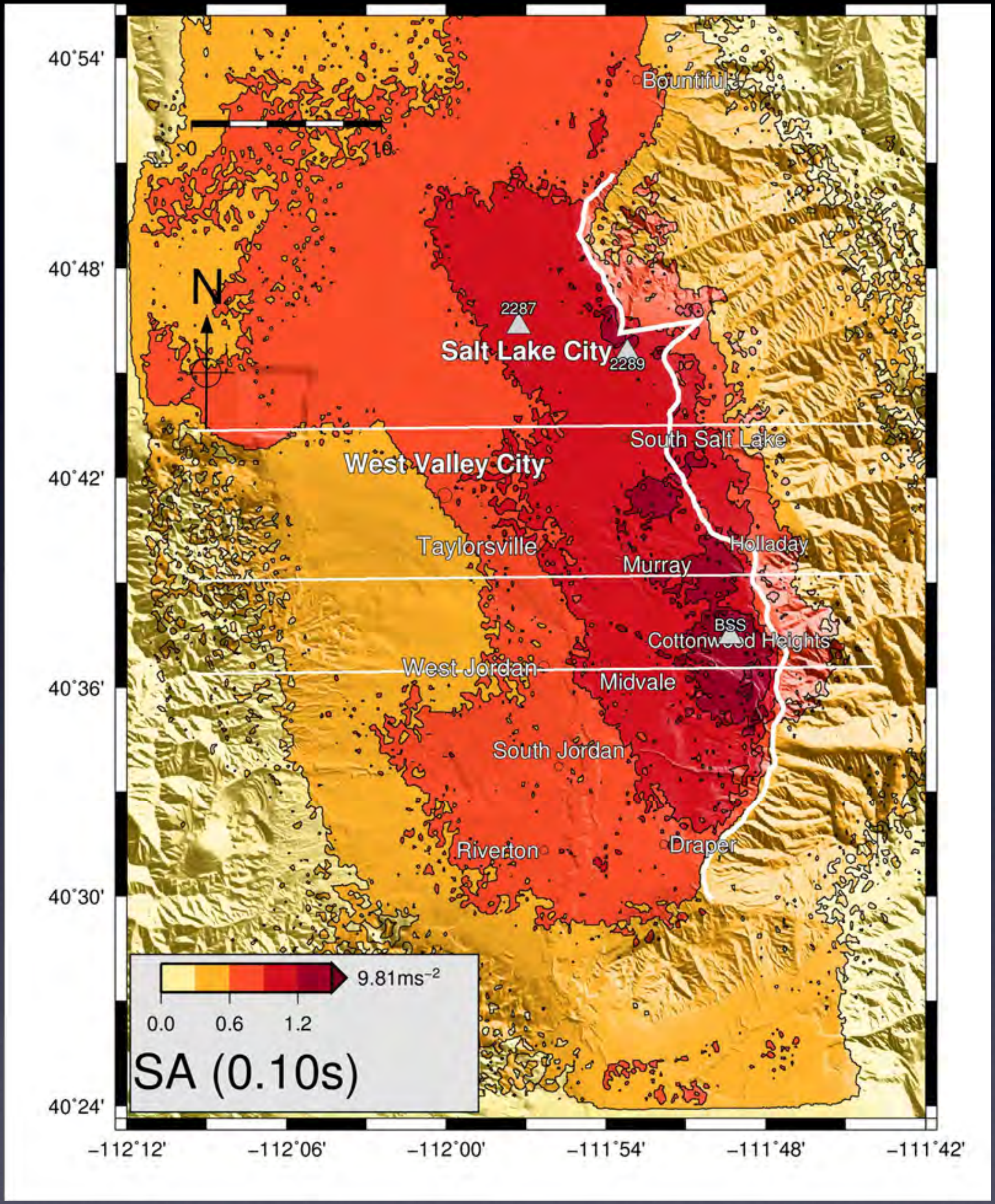
Ensemble SA(0.5s)



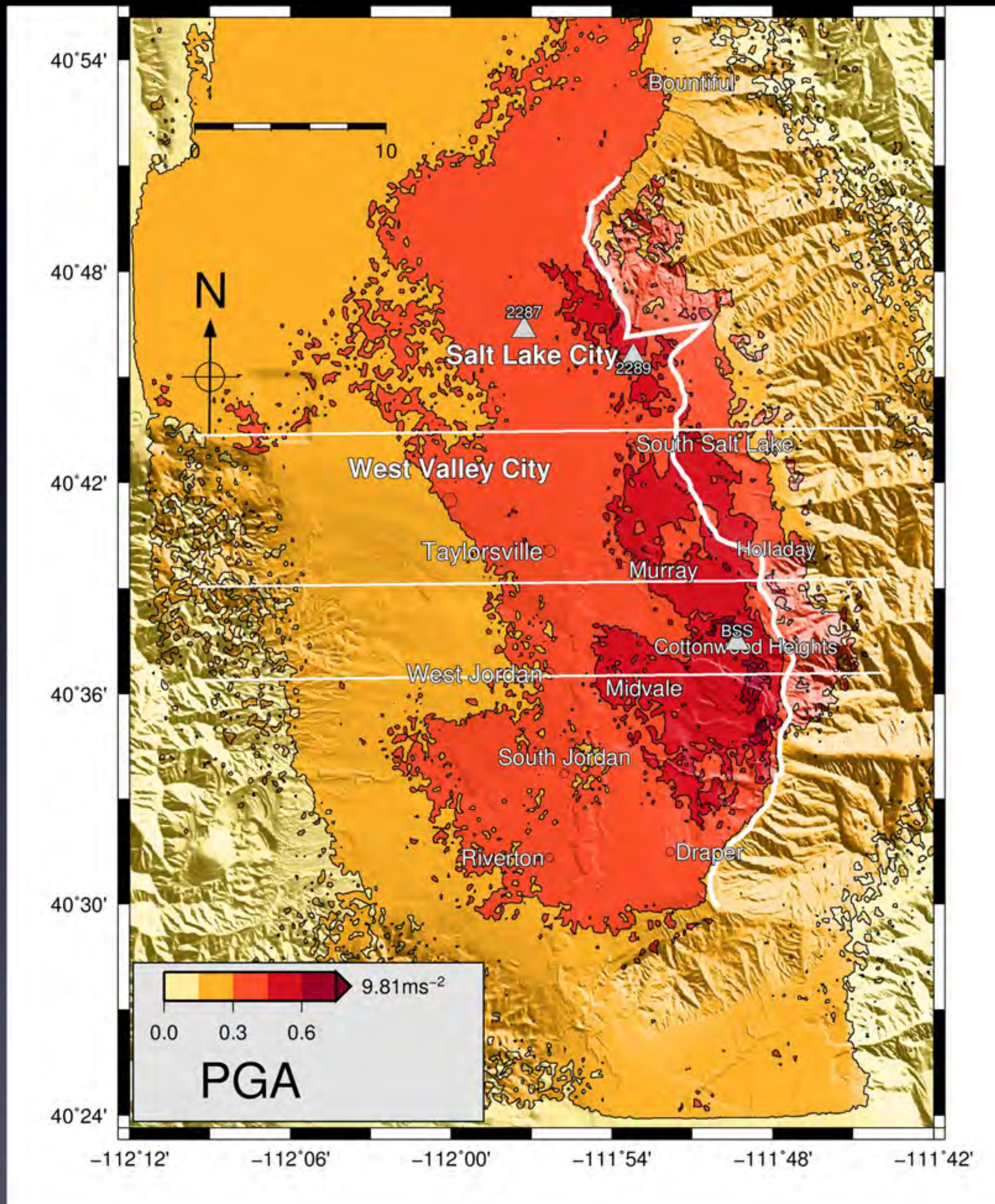
Ensemble SA(0.2s)



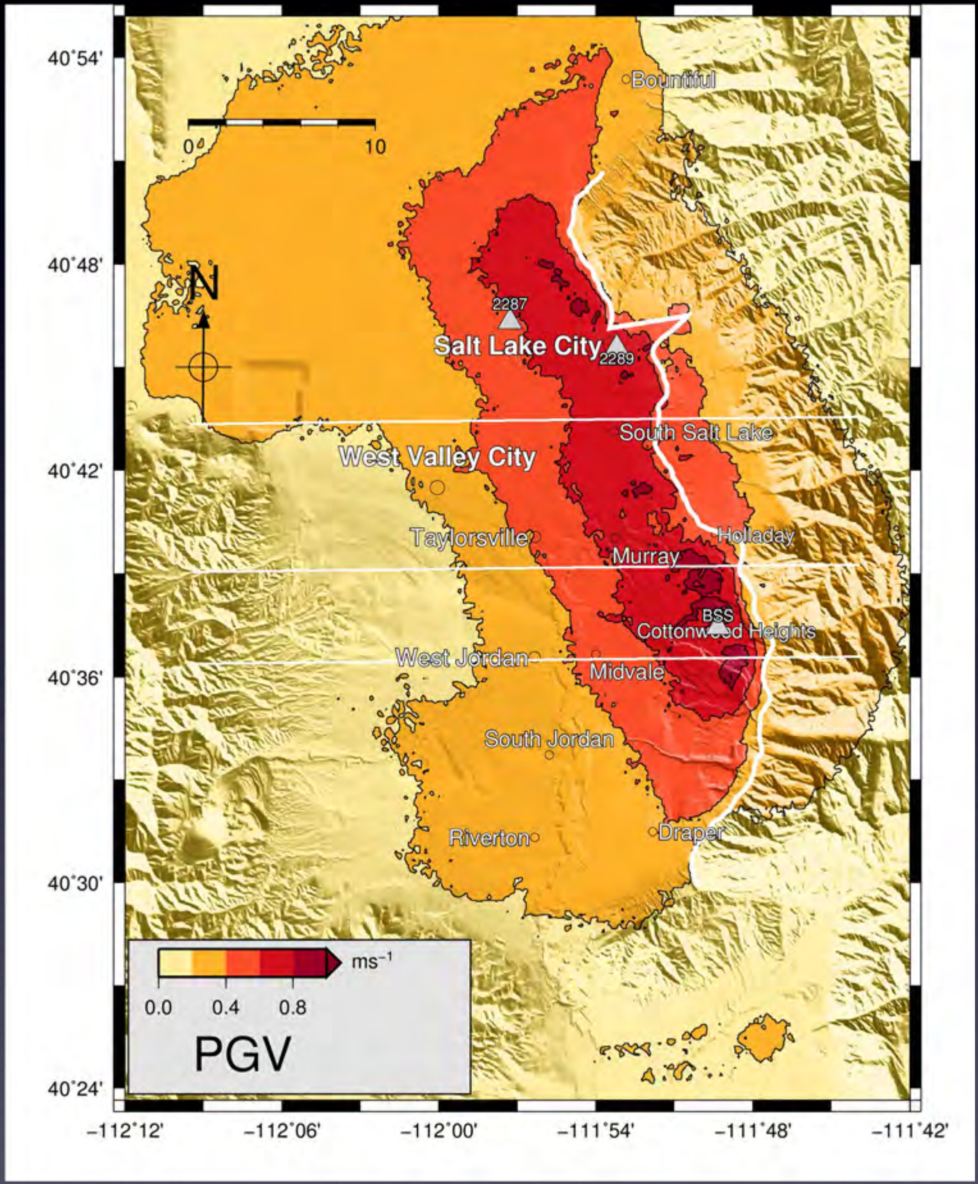
Ensemble SA(0.1s)

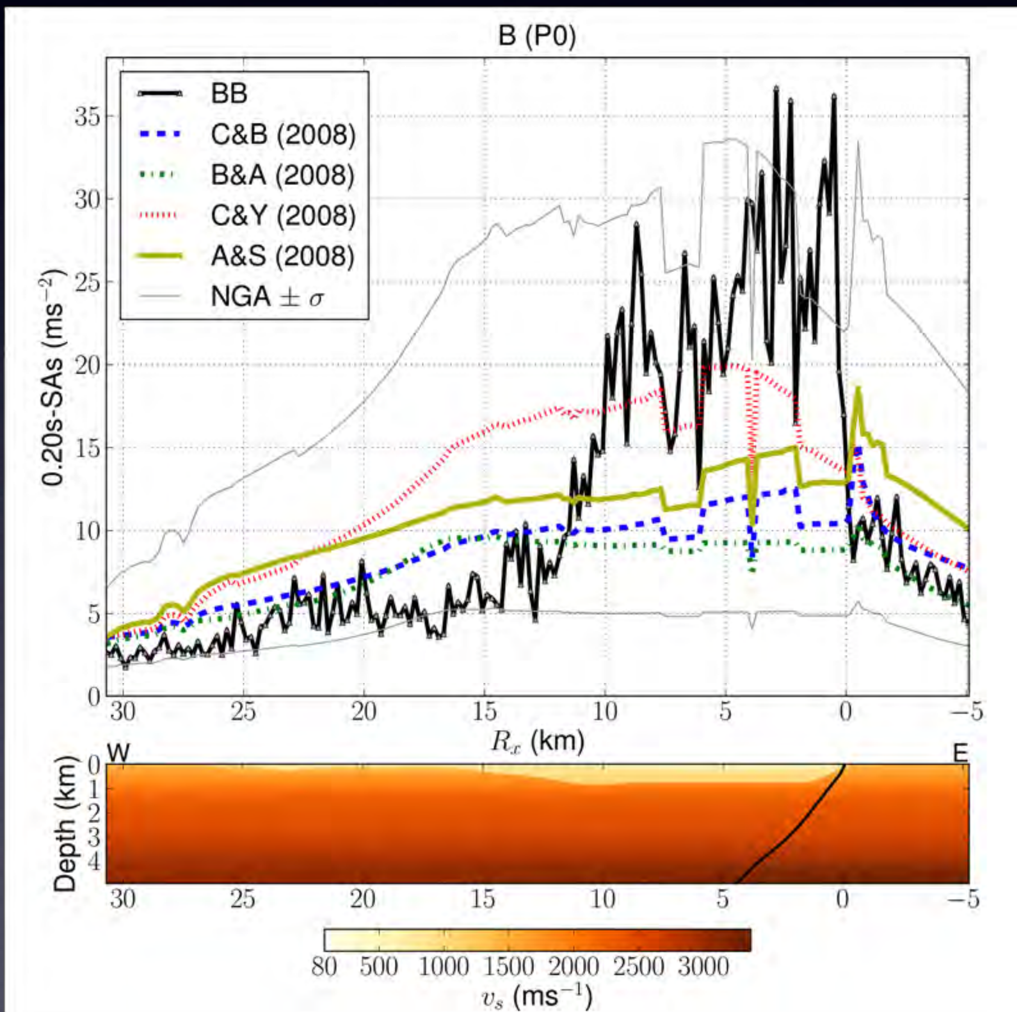


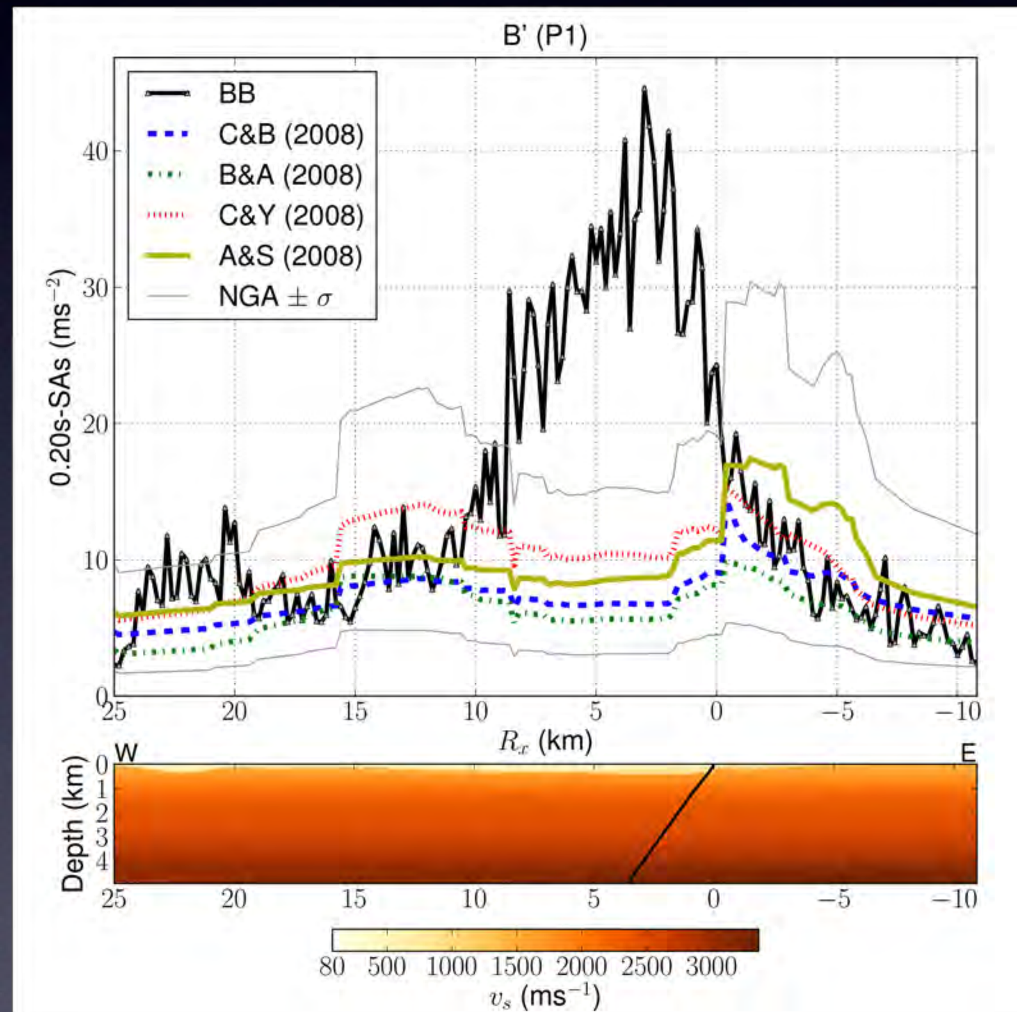
Ensemble PGA

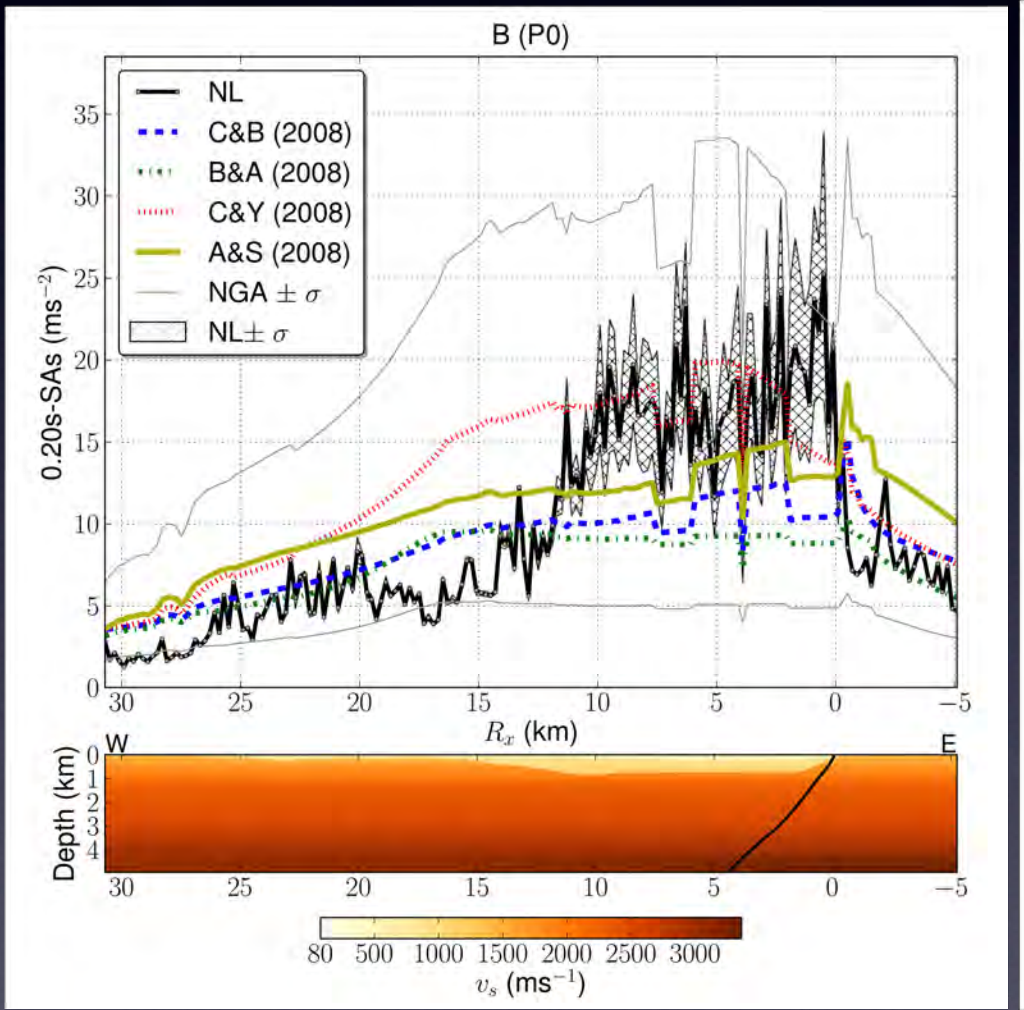


Ensemble PGV

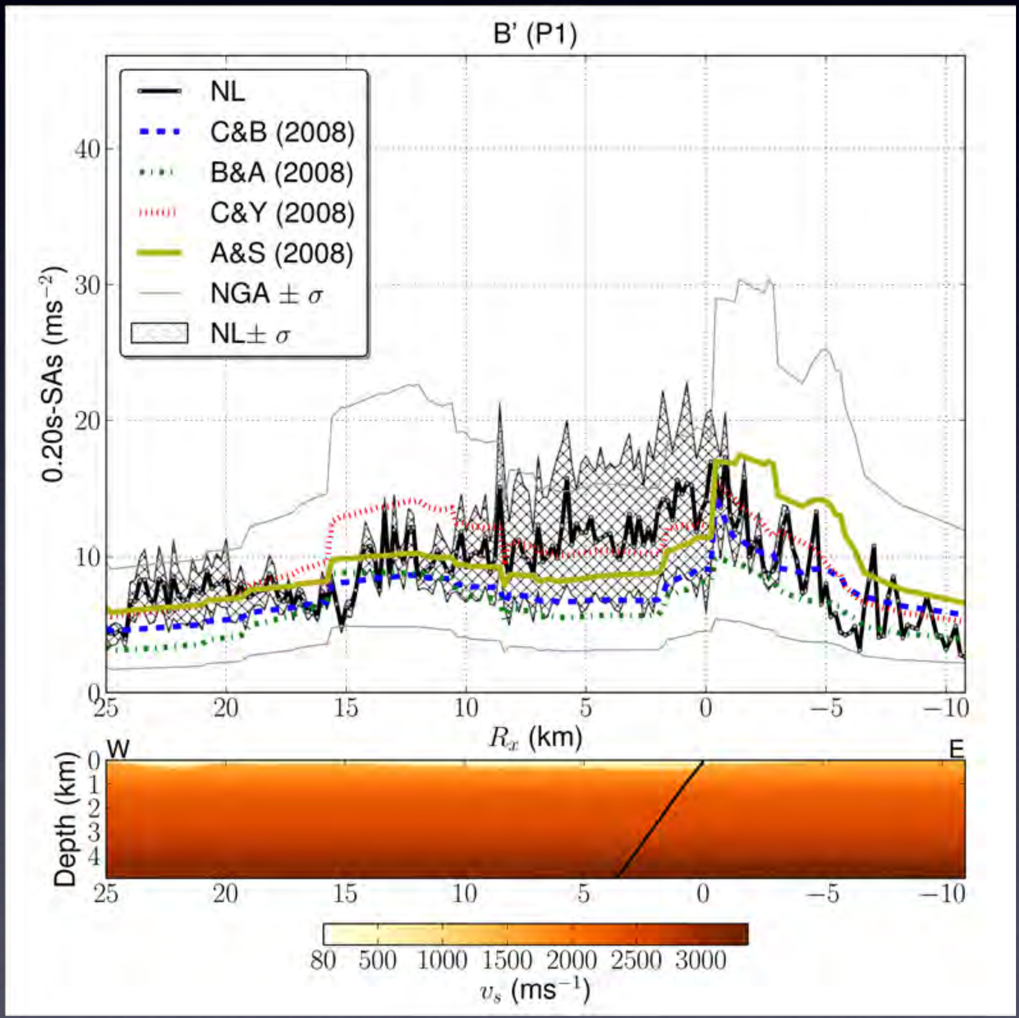



B (P0)
BB
C&B (2008)
B&A (2008)
C&Y (2008)
A&S (2008)
NGA ± σ
0.20s-SAs (ms^-2)
R_x (km)
W
E
Depth (km)
v_s (ms^-1)

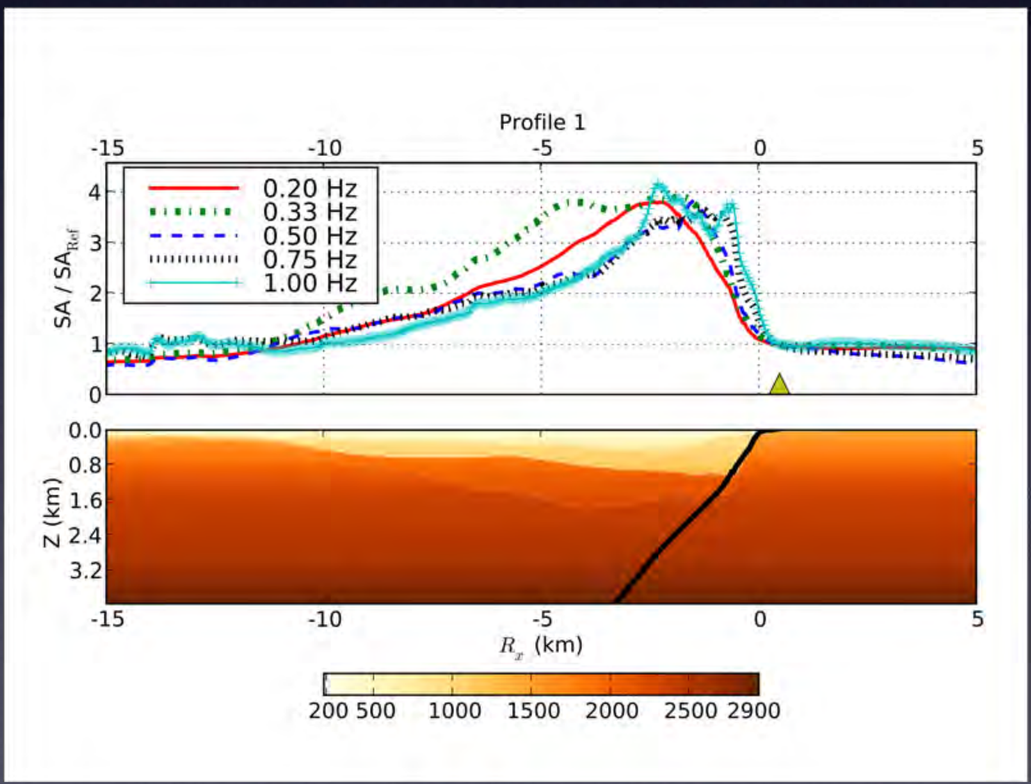

B' (P1)
BB
C&B (2008)
B&A (2008)
C&Y (2008)
A&S (2008)
NGA ± σ
0.20s-SAs (ms^-2)
R_x (km)
W
E
Depth (km)
v_s (ms^-1)



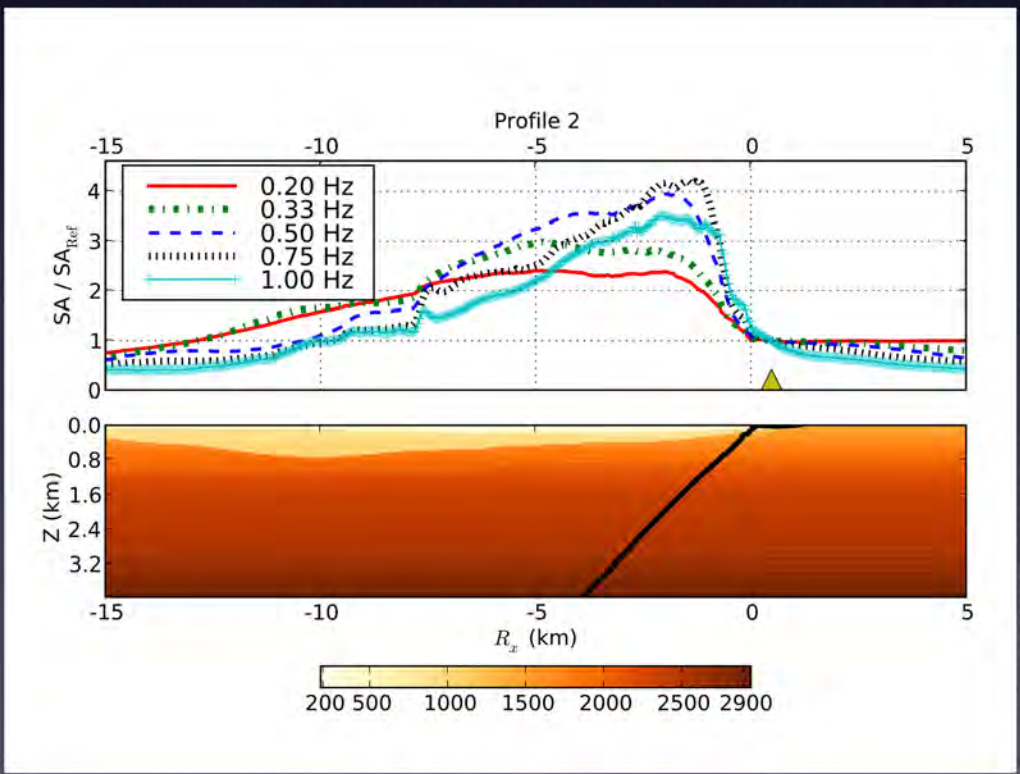
B (P0)
NL
C&B (2008)
B&A (2008)
C&Y (2008)
A&S (2008)
NGA ± σ
NL± σ
0.20s-SAs (ms⁻²)
Rx (km)
W
E
Depth (km)
vs (ms⁻¹)



B' (P1)
NL
C&B (2008)
B&A (2008)
C&Y (2008)
A&S (2008)
NGA ± σ
NL± σ
0.20s-SAs (ms⁻²)
Rx (km)
W
E
Depth (km)
vs (ms⁻¹)



Profile 1
0.20 Hz
0.33 Hz
0.50 Hz
0.75 Hz
1.00 Hz
SA / SA_Ref
Z (km)
R_x (km)
200 500 1000 1500 2000 2500 2900

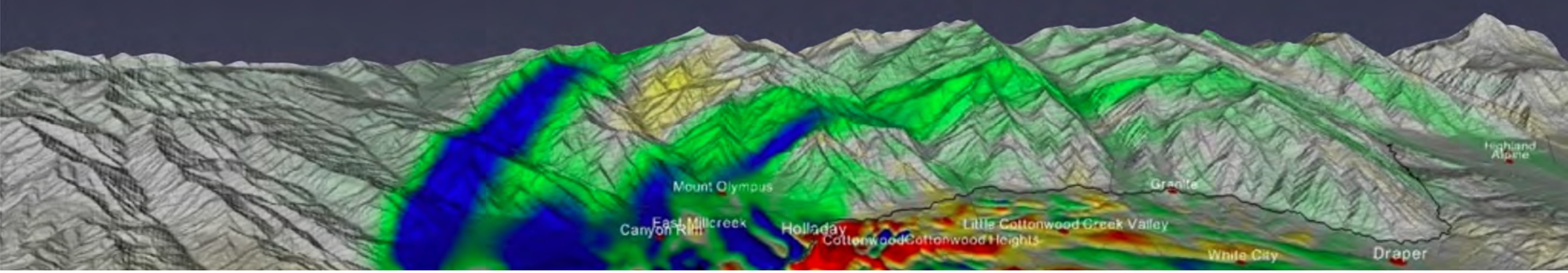


Profile 2
0.20 Hz
0.33 Hz
0.50 Hz
0.75 Hz
1.00 Hz
SA / SA_Ref
Z (km)
R_x (km)
200 500 1000 1500 2000 2500 2900

Conclusions I

0-1 Hz 3-D FD simulations of scenario earthquakes

- Ground motion tends to be larger on the low-velocity sediments on the hanging wall side of the fault than on outcropping rock on the footwall side, confirming results of previous studies on normal faulting EQs (O'Connell et al., 2007)
- The simulated ground motions reveal strong along-strike and along-dip directivity effects
- Our simulations suggest that the highest average 2s-SAs occur at ~2-3 km distance from the surface trace of the fault
- 2s-SAs and 1s-SAs are in agreement with values predicted by NGA models



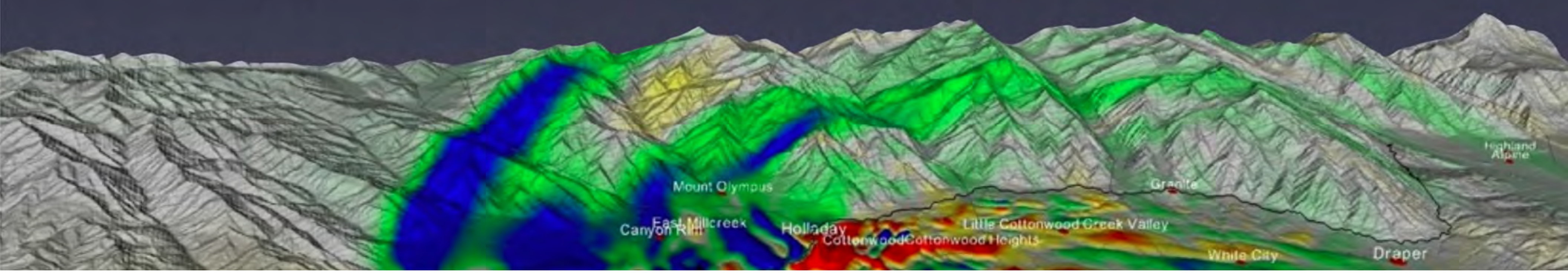
Conclusions II

Broadband (0-10Hz) synthetics:

- 0.2s-SAs derived from broadband synthetic seismograms are exceeding those predicted by NGA models by more than one standard deviation at near-fault locations on the hanging wall side, but agree well at some distance from the fault
- Compared to Solomon et al. (2004), our 3-D FD simulations predict lower 1s-SAs on the footwall wall side of the fault

Nonlinear soil response:

- Synthetic ground motions obtained from a fully nonlinear 1-D propagator exhibit PGAs and SAs that are consistent with values predicted by NGA models, even when taking into account the uncertainty in the nonlinear soil parameters
- Higher-frequency (> 2Hz) ground motion is controlled by nonlinear site response, with larger SAs on the shallow sediments on the footwall side than on the deep sediments on the hanging wall side



Curved Dynamic Rupture Model For The Wasatch Fault SLC Segment

Qiming Liu and Ralph Archuleta,
University of California, Santa Barbara

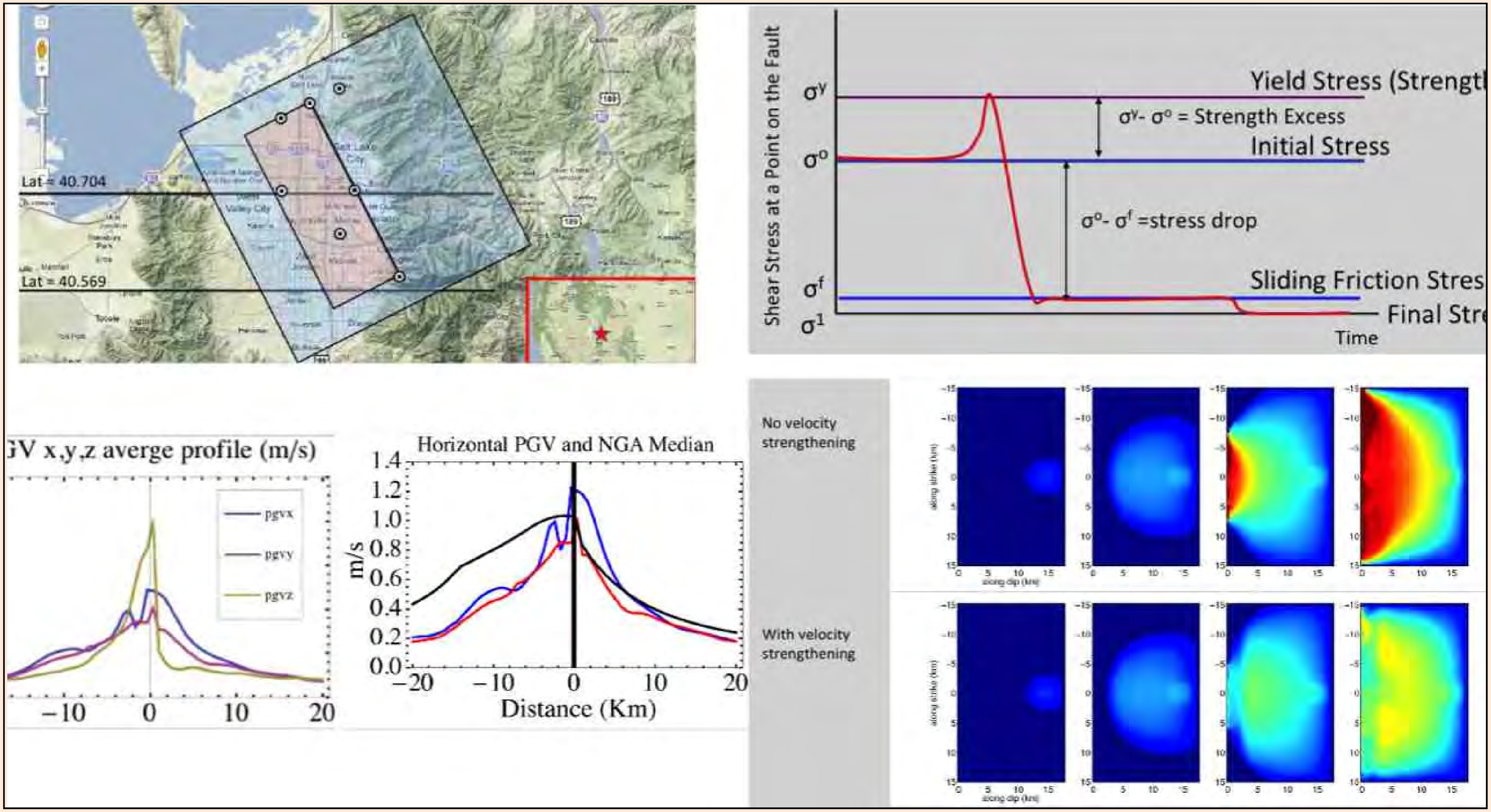
Bob Smith
University of Utah

UGSWG 2012 Meeting, Salt Lake City

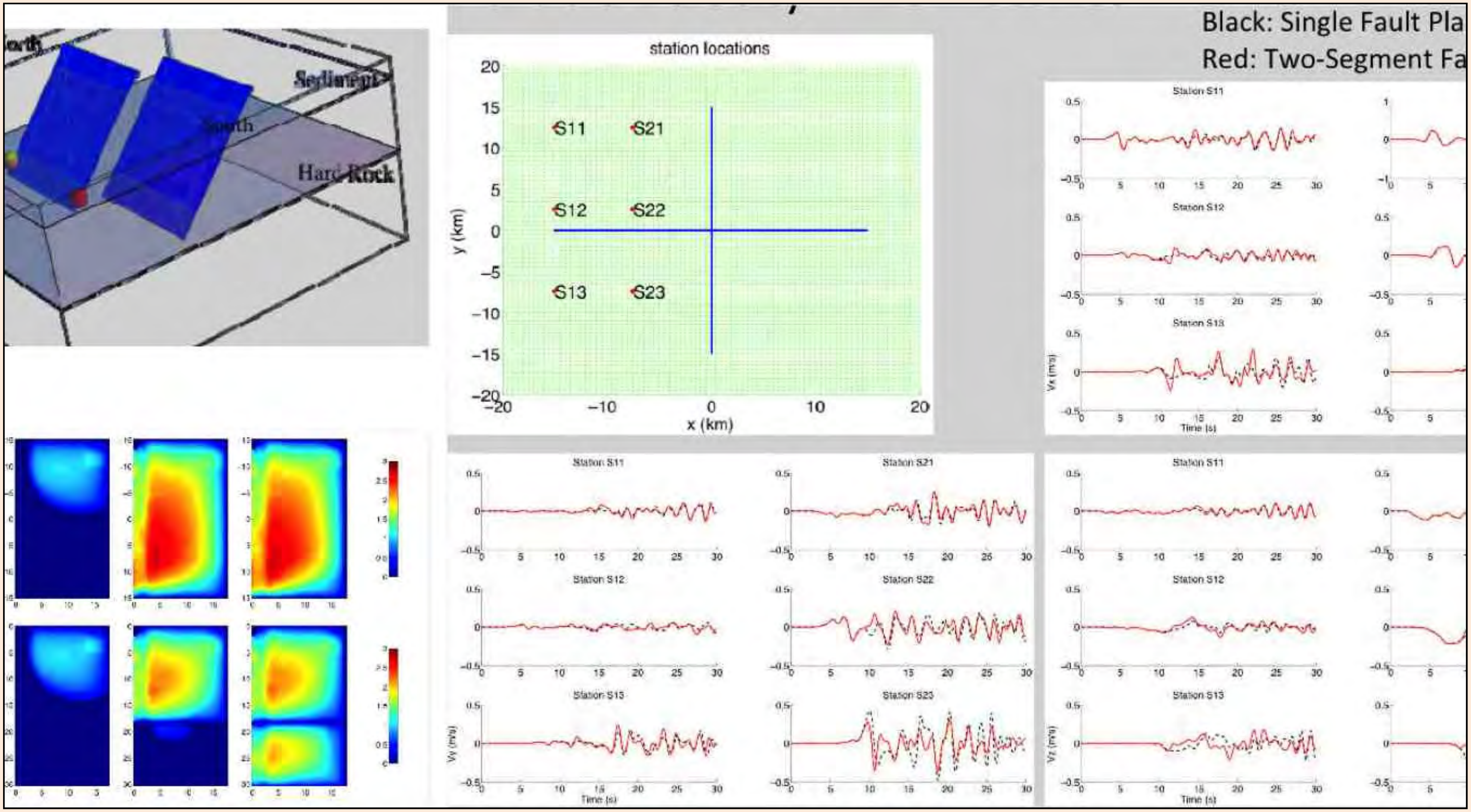
Outline

- Review of previous results
- Dynamic rupture model setting up
- Fault representation in different scales
- Directivity effect and its implication
- 1Hz result without the Kink

Previous Results (1)

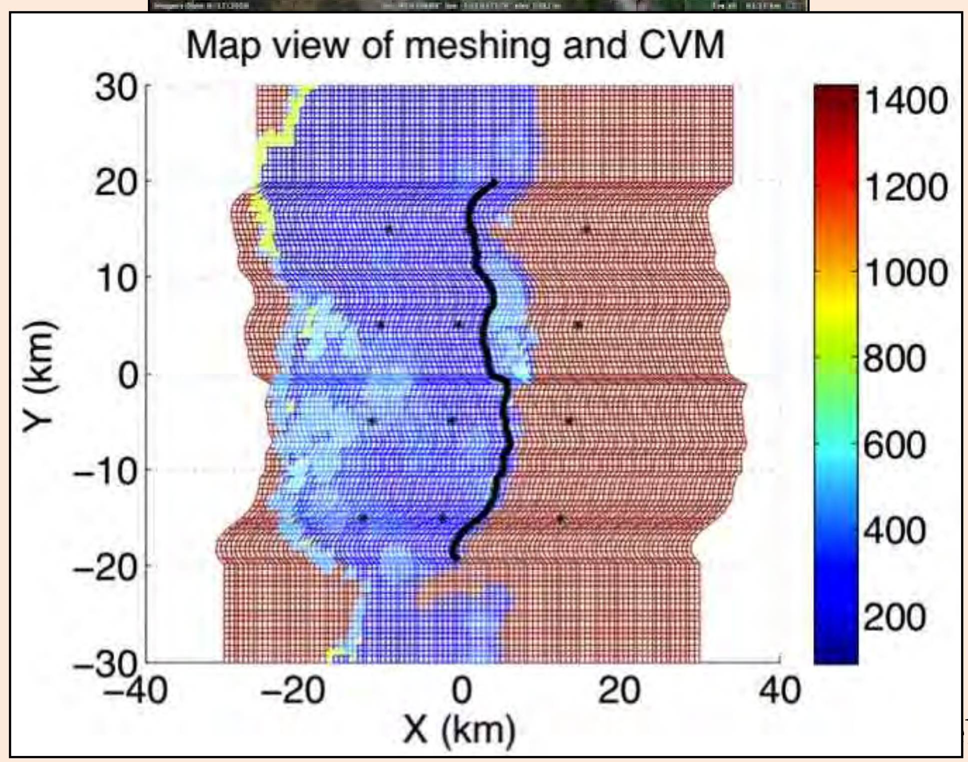


Previous Results (2)



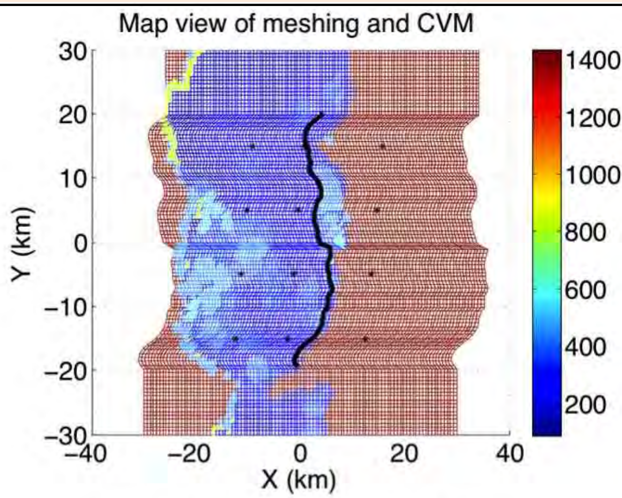
Model Set-up

Lx, Ly, Lz	60 km, 60 km,17 km
dx, dy, dz	<200 m, < 200 m , <200 m
Friction law	Slip-weakening
Dc	0.25 m
Initial normal stress	35.97MPa or 5.37MPa/km
Initial shear (dip) stress	0.55*initial normal stress
Tmax	20 s
Dt	<0.005 s
Vs minimum	500 m/s
µd, µs	0.448, 0.66
Velocity Strengthening layer	Top 3 km

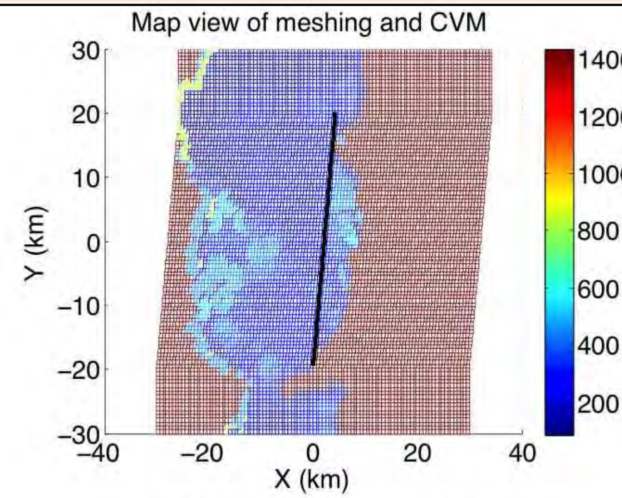


Fault Representation In Different Scales

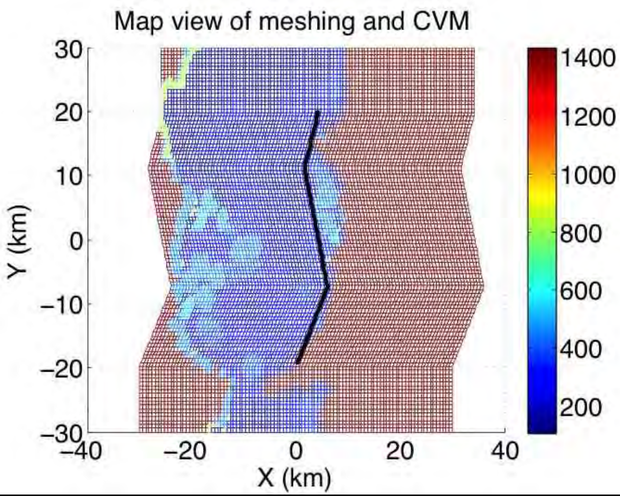
(A)



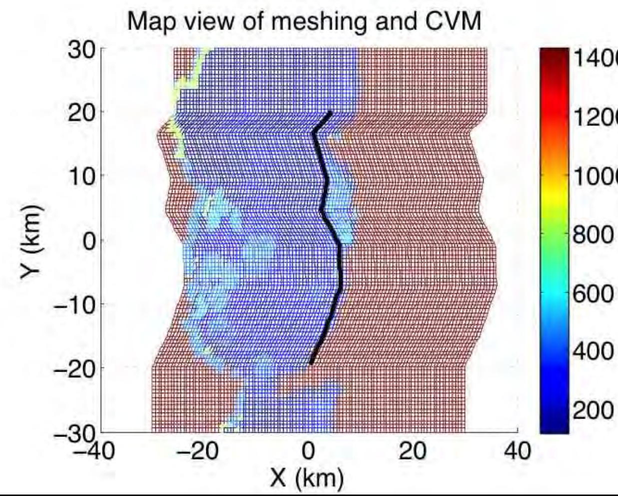
(B)



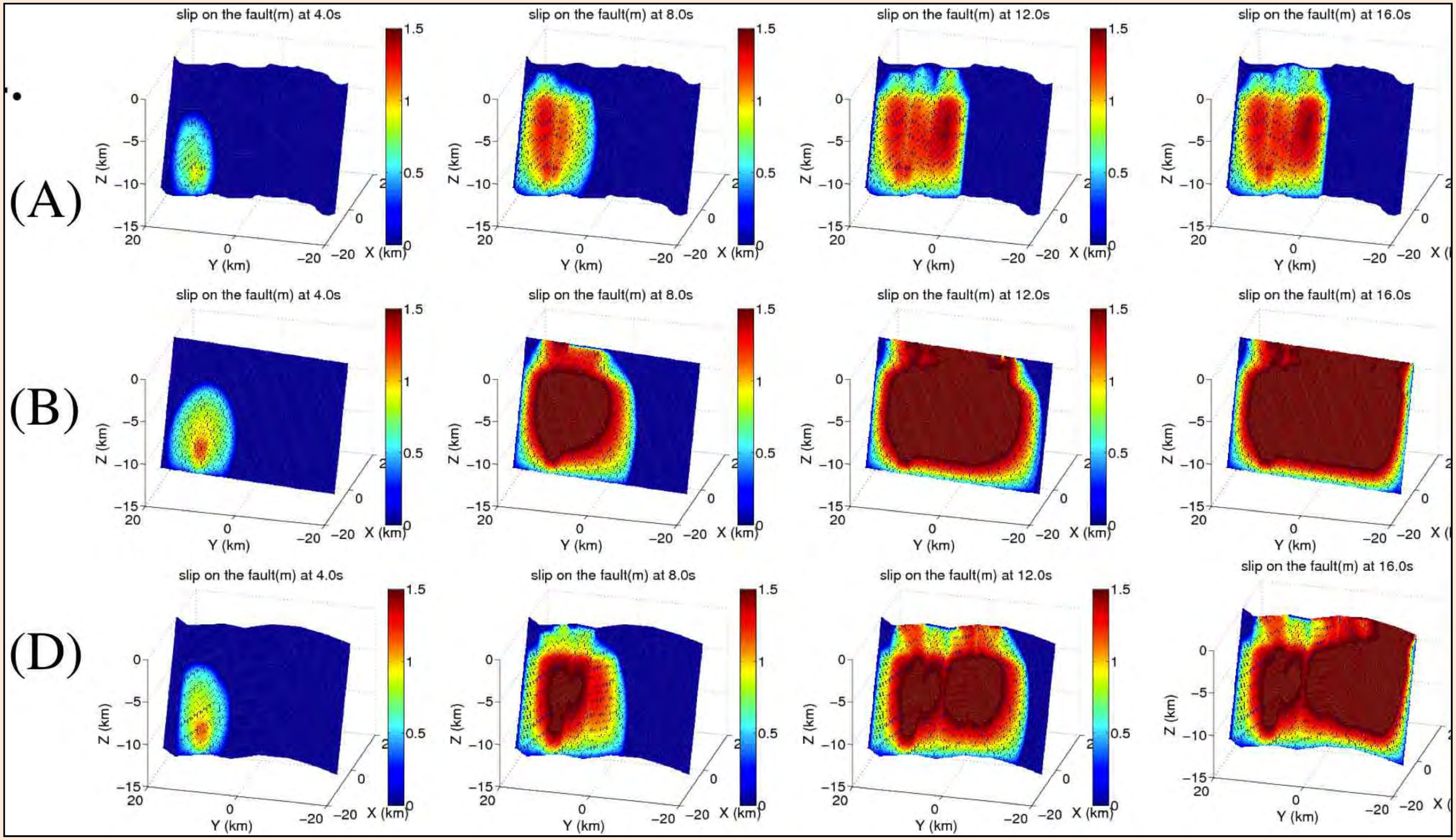
(C)



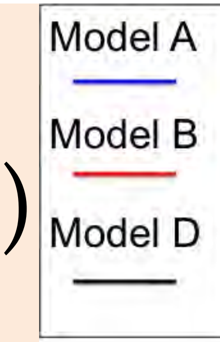
(D)

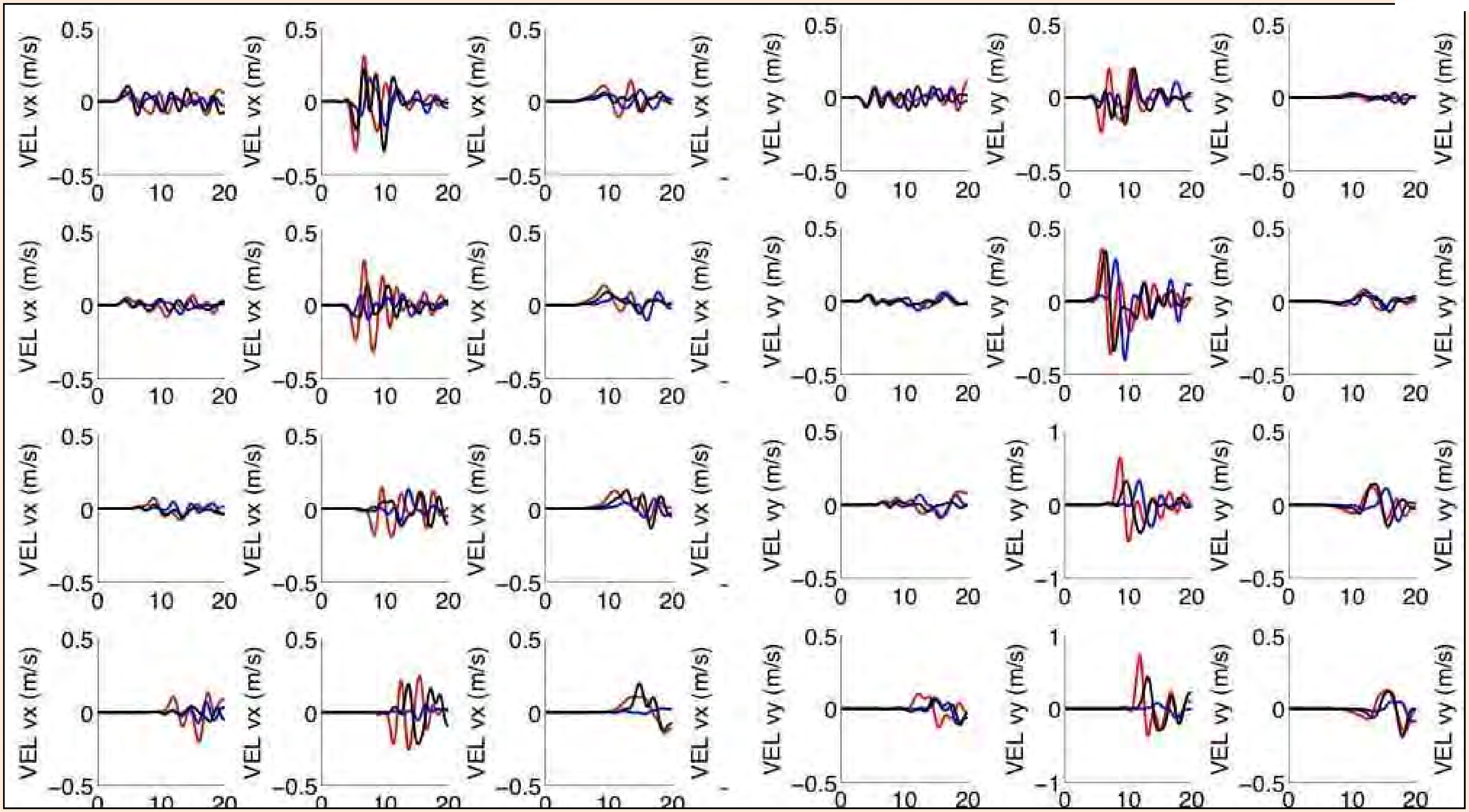


Fault Representation In Different Scales (2)



Fault Representation In Different Scales (3)



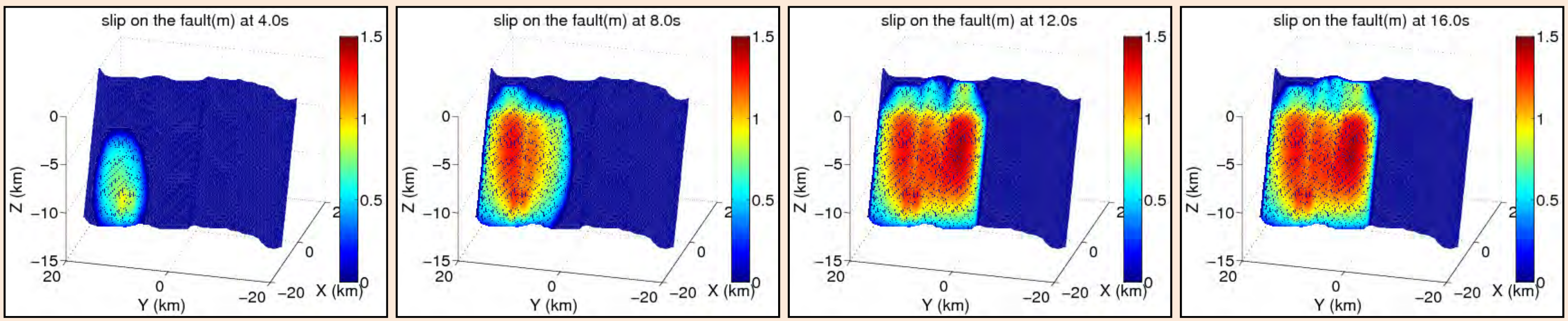


0.5Hz ground motion comparison (between model A B and D) at stations shown in slide 6 as dots

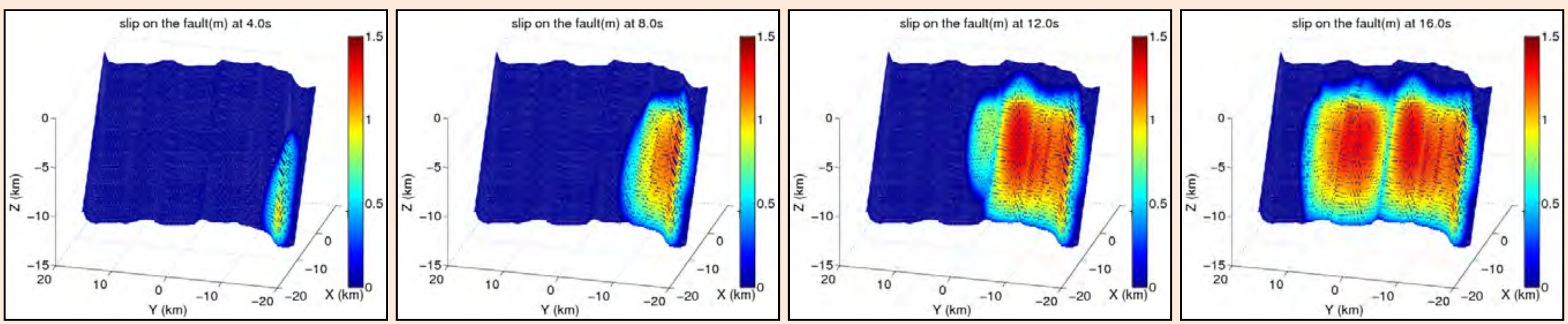
Directivity Effect And Its Implication

- comparison of two sources
- 0.5Hz (dx = 100m)

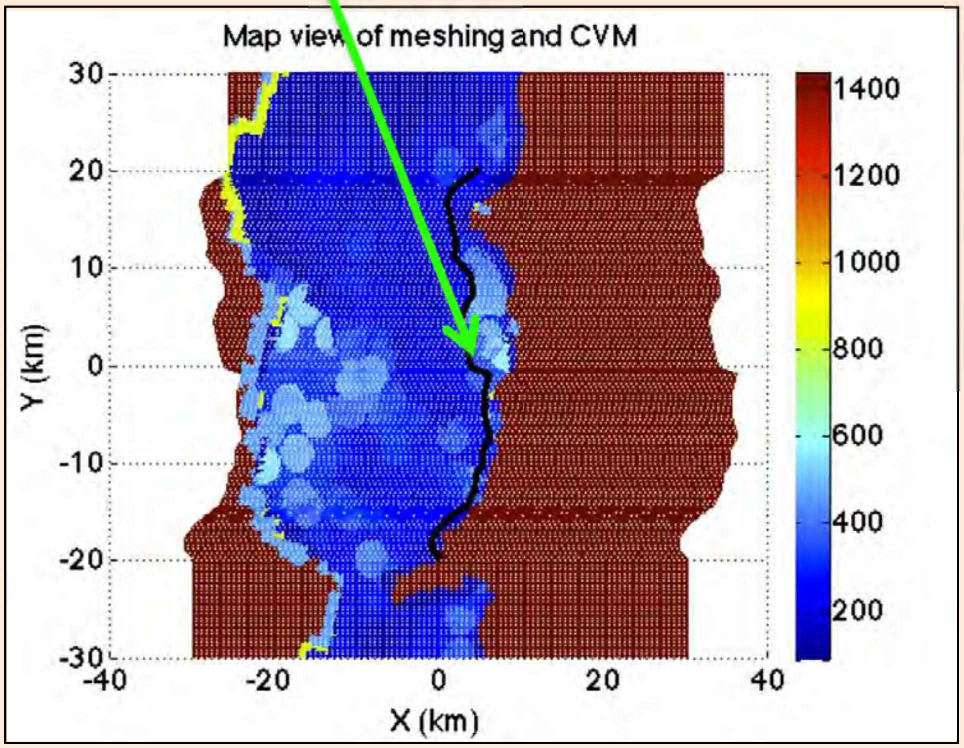
Source at north

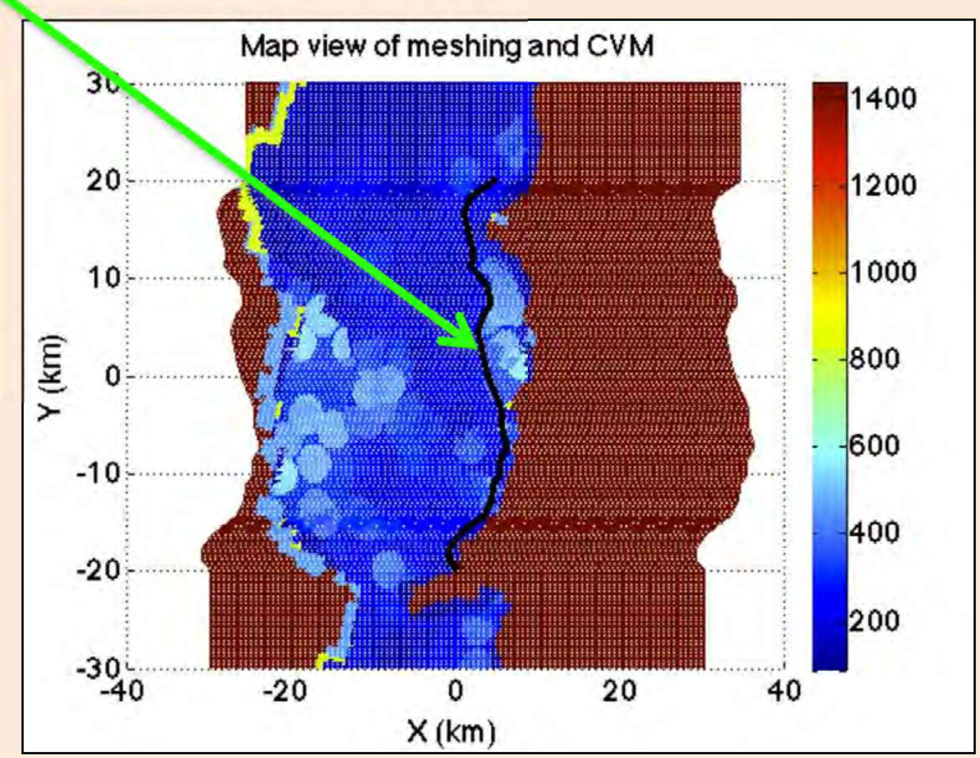


Source at south



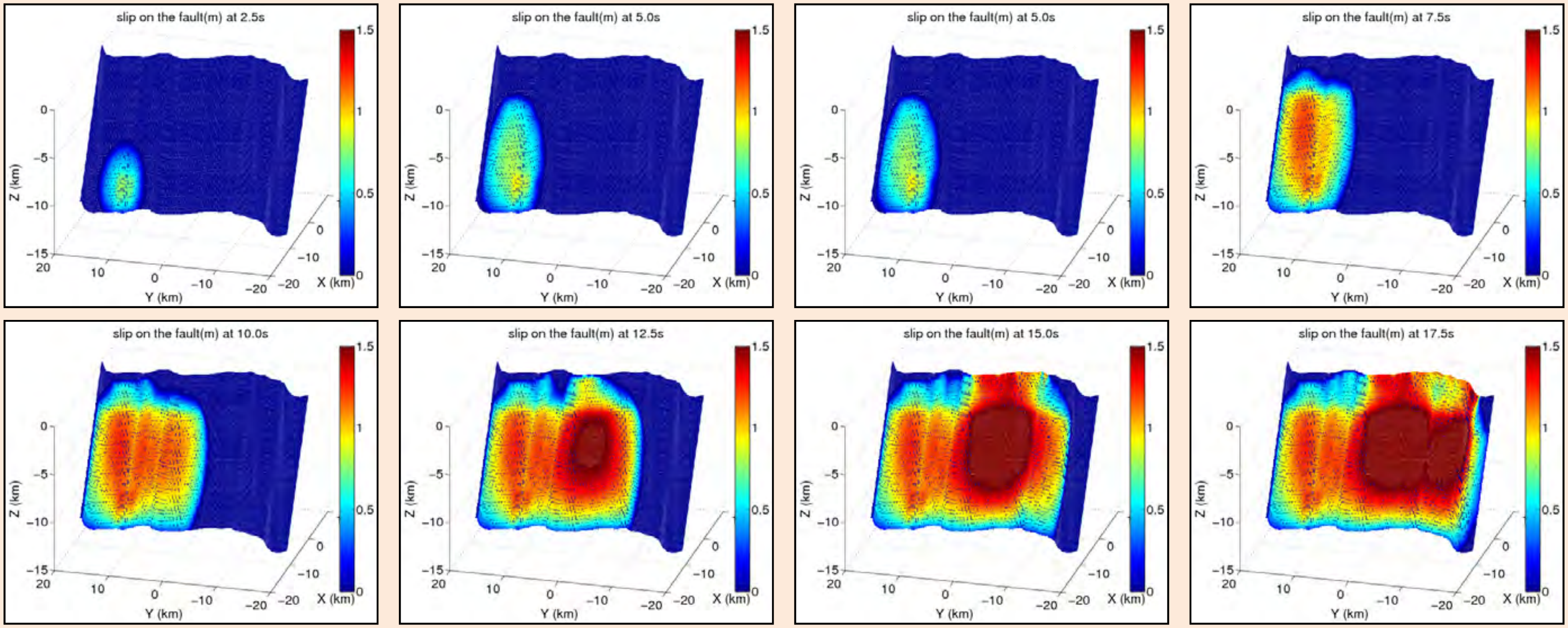
1.0 Hz Result
With and Without The Fault Kink

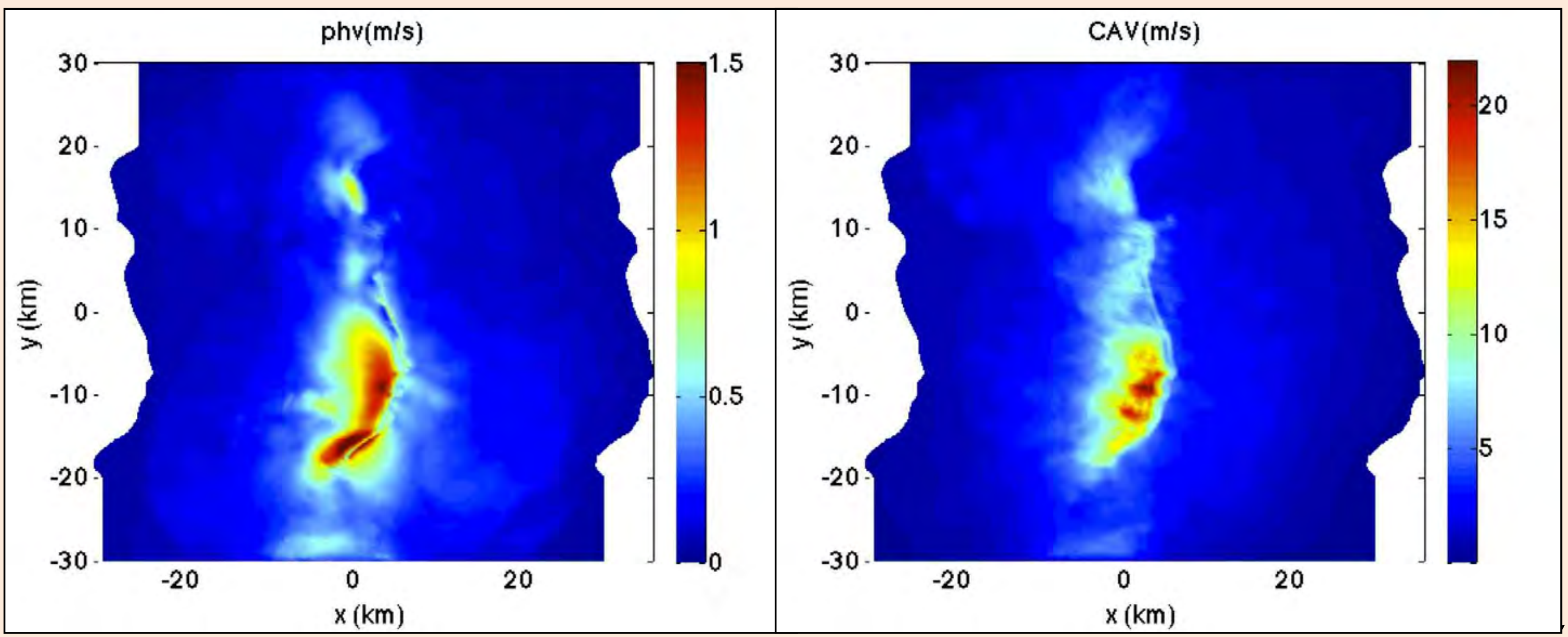




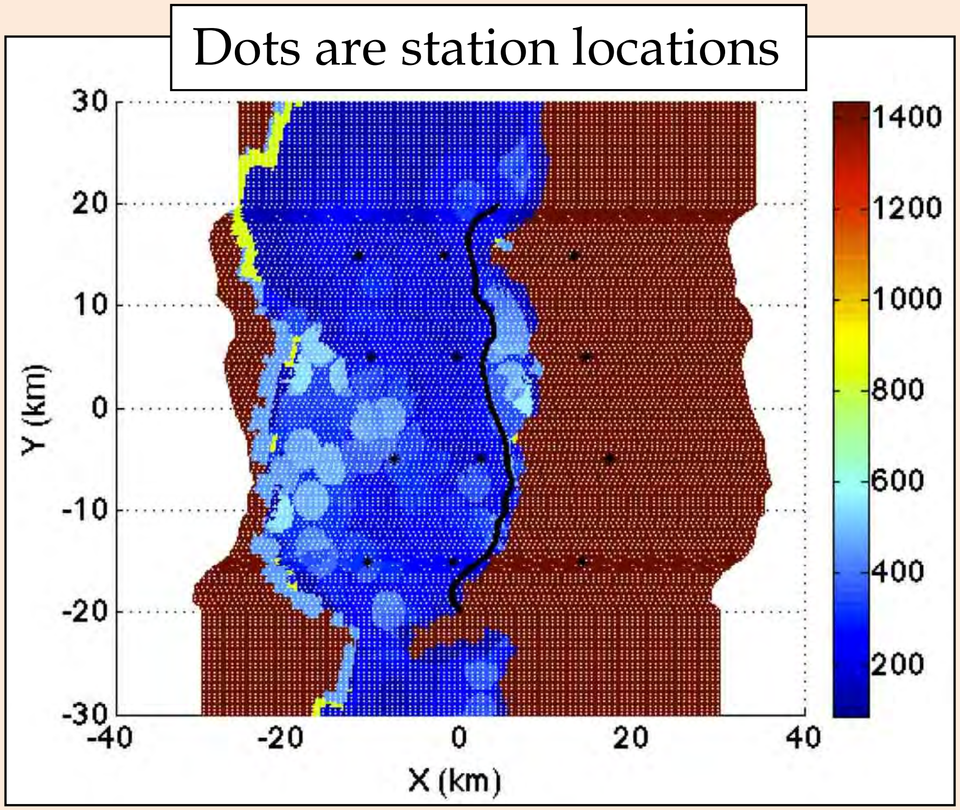
Fault geometry model with (left) and without (right) the kink

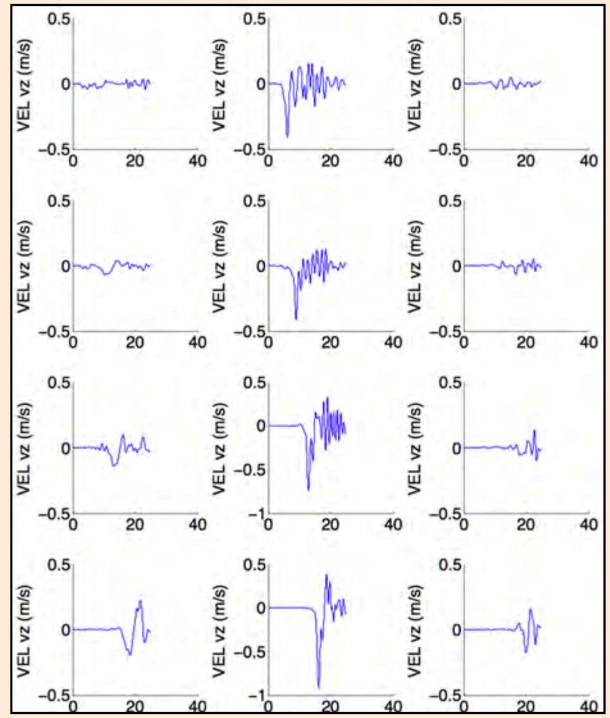
Simulation Earthquake Mw: 6.85

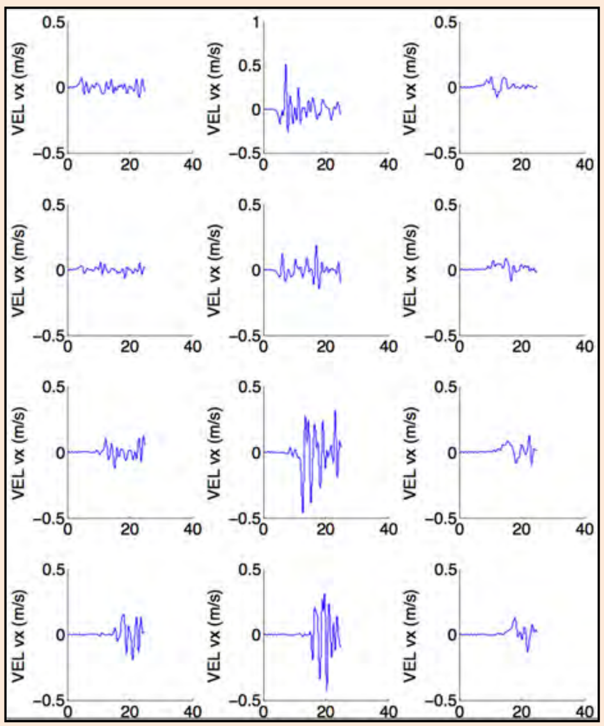

slip on the fault(m) at 2.5s
slip on the fault(m) at 5.0s
slip on the fault(m) at 5.0s
slip on the fault(m) at 7.5s
slip on the fault(m) at 10.0s
slip on the fault(m) at 12.5s
slip on the fault(m) at 15.0s
slip on the fault(m) at 17.5s
Z (km)
Y (km)
X (km)

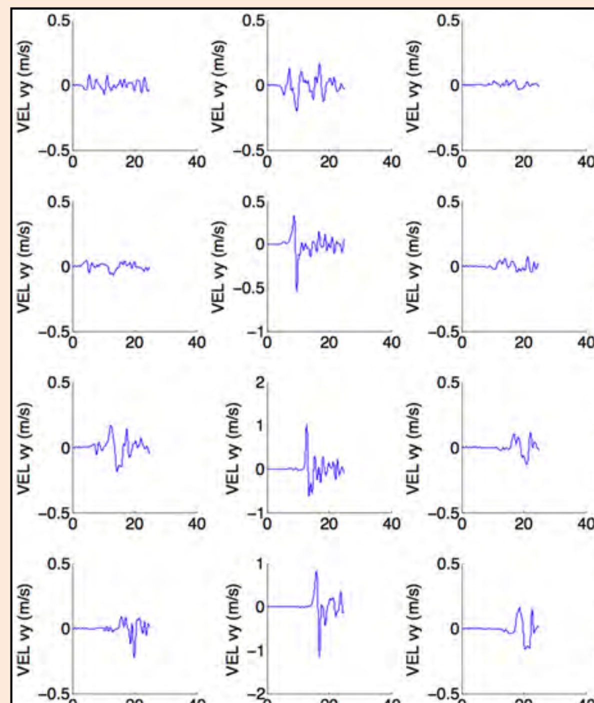

phv(m/s)
CAV(m/s)
y (km)
x (km)

, 2012

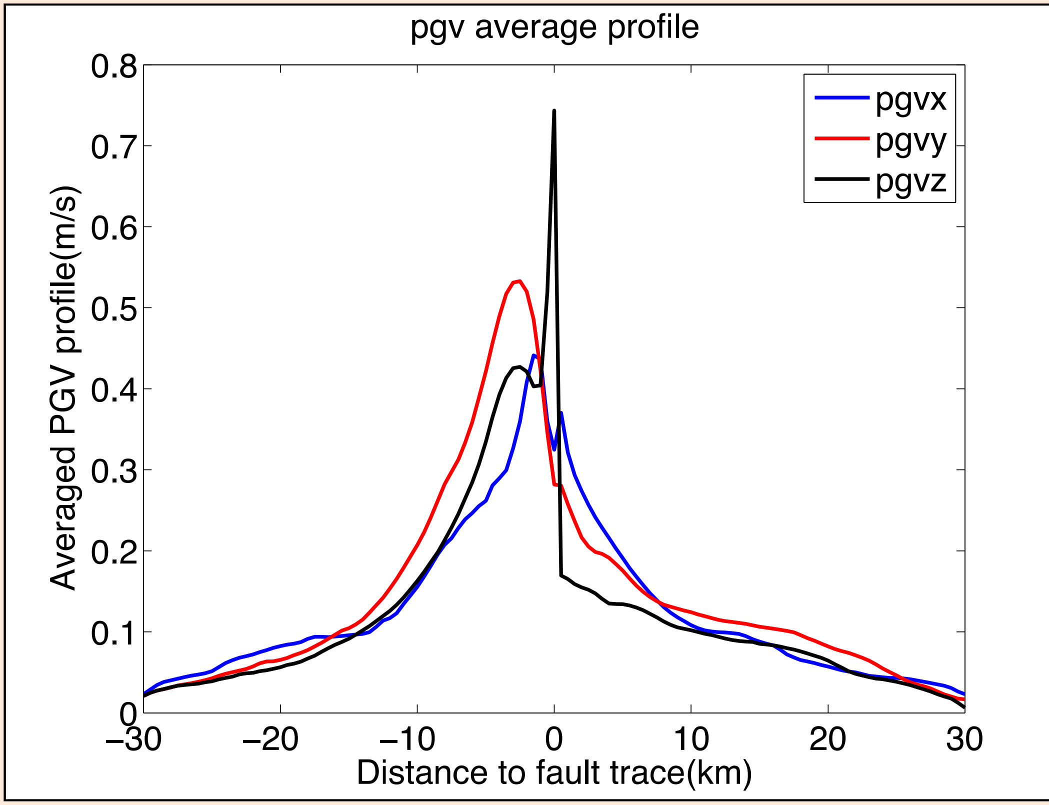

Dots are station locations
Y (km)
X (km)
1400
1200
1000
800
600
400
200

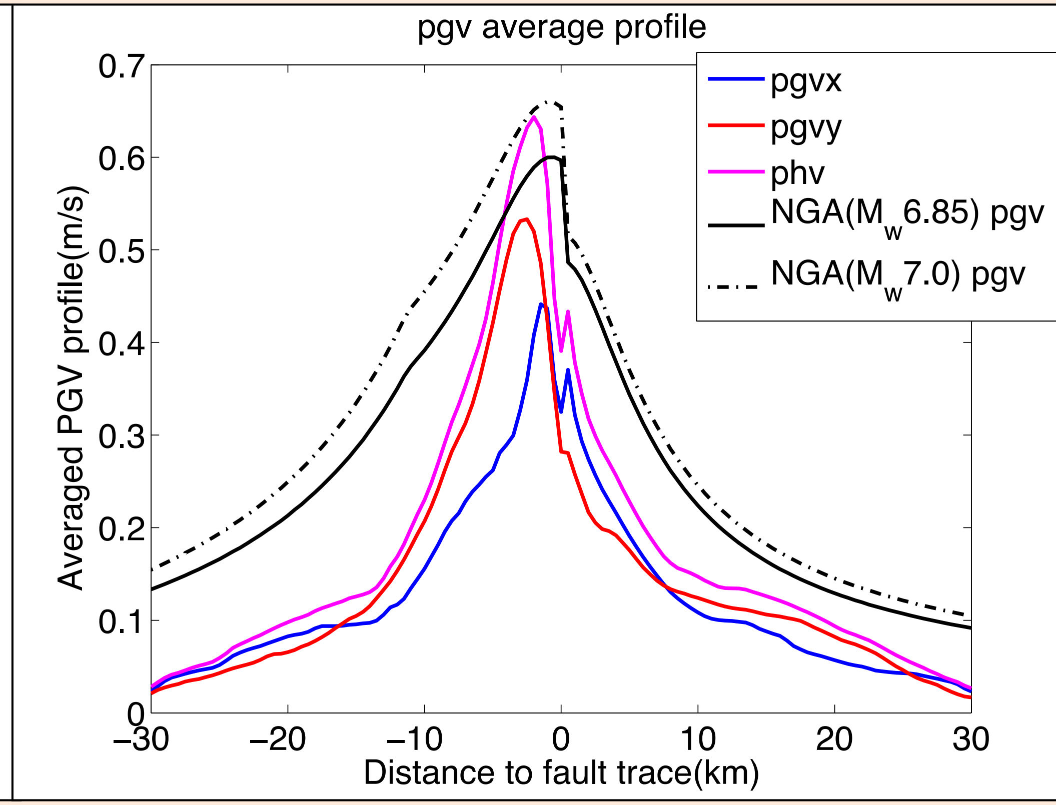

VEL vz (m/s)


VEL vx (m/s)

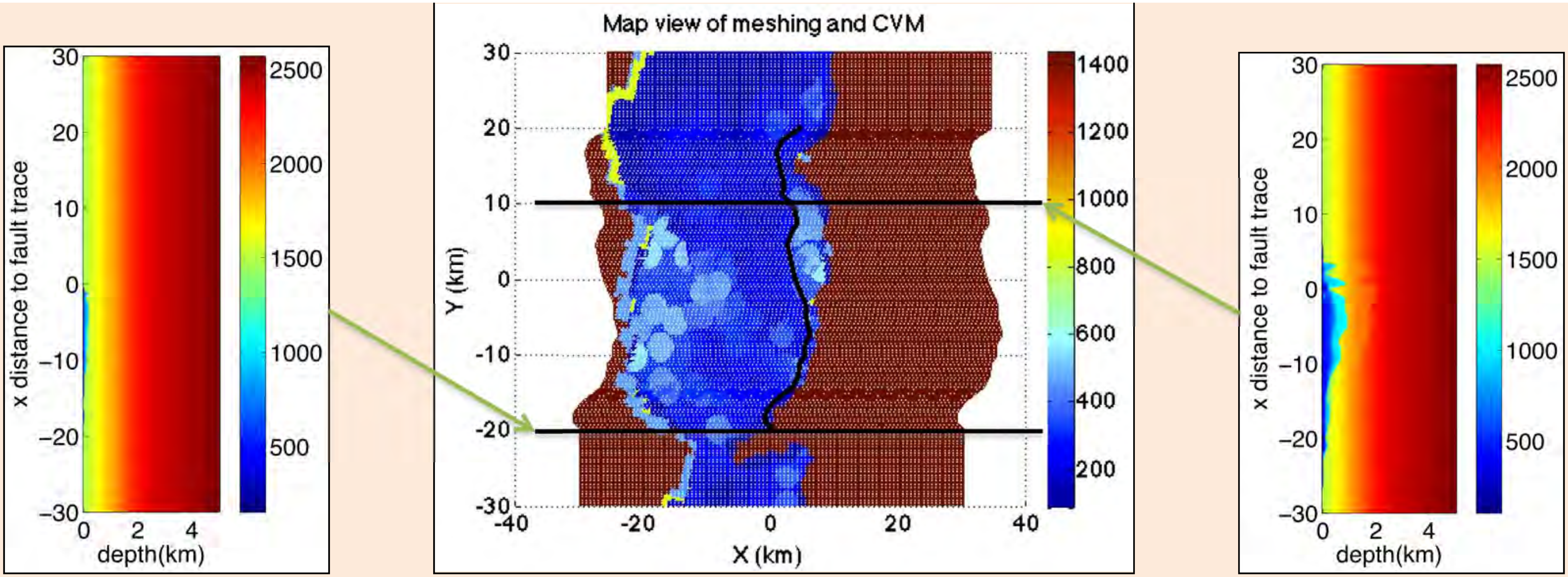

VEL vy (m/s)

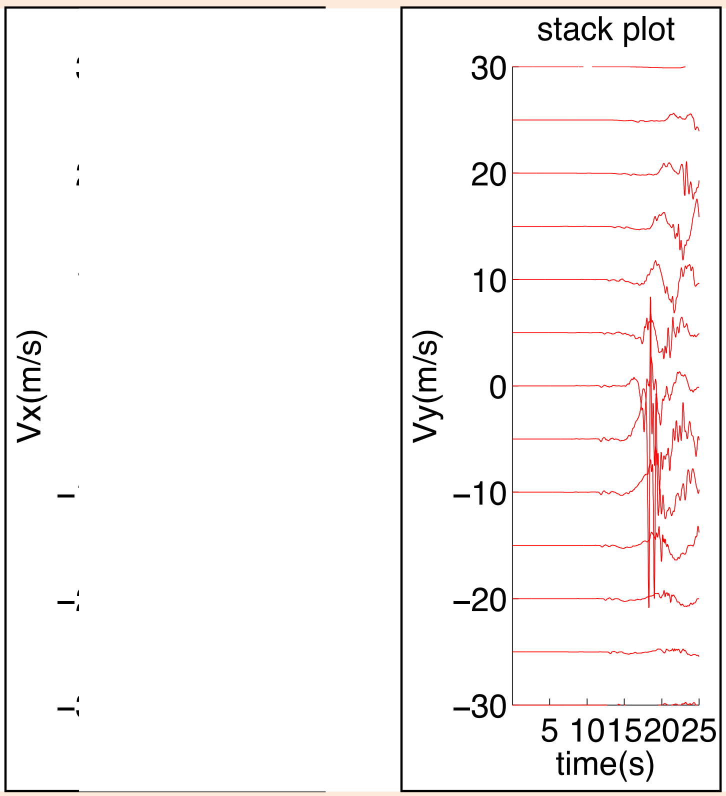
PGV Profile
And Its Comparison With NGA Model



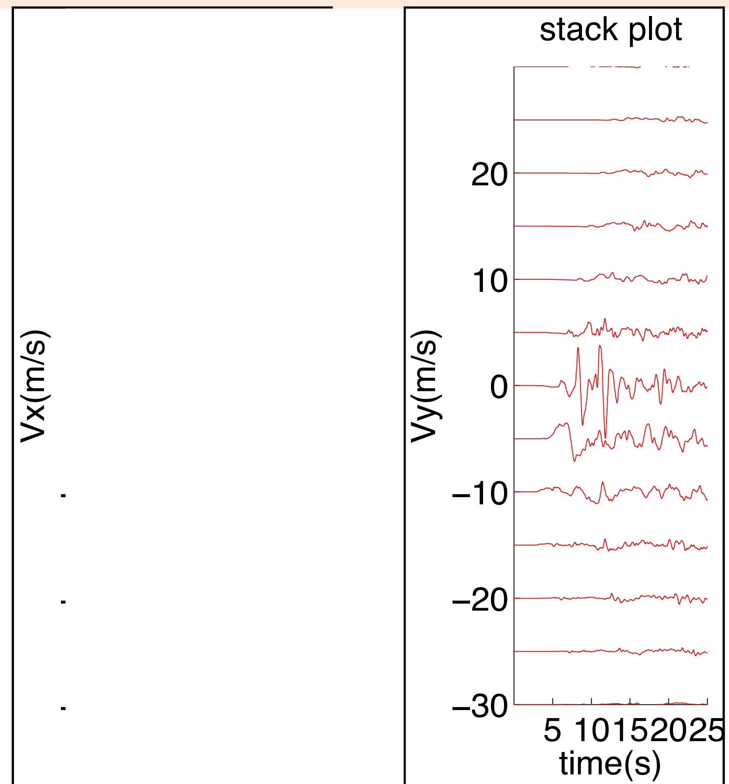


Hanging wall(-) ------- Footwall(+)





Velocity structure (Vs in m/s) cross sections and calculated ground motions on top of the profiles.



Conclusion

- More physical-based earthquake simulation and ground motion calculations up to 1Hz from dynamic ruptures on dipping faults with geometrical complexities.
- Modeling the details of the fault matters: fault geometry (stepovers/kinks) can impede rupture thus change the slip and slip rate pattern on the fault.
- 3D velocity structure has direct impact on ground motion--low velocity in the basin increases duration of shaking as well as amplifying the motion.
- Velocity strengthening behavior near the free surface provides a physically justified mechanism to reduce the fault slip to a level consistent with paleoseismological evidence.
- The vertical component of ground motion is not trivial due to the fairly steep dip angle of the Wasatch Fault.

Earthquake ground motion modeling with kinematic source models:

Preliminary low-frequency ground motions and effects of velocity perturbations to WCVM

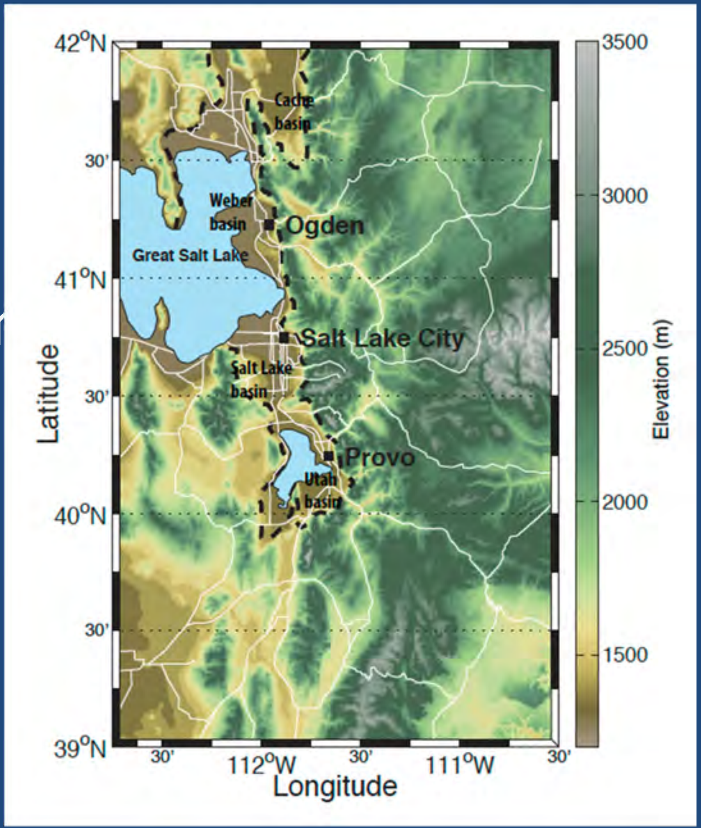
Morgan Moschetti and Leonardo Ramirez-Guzman

Utah Ground Shaking Working Group

2012 UEWG

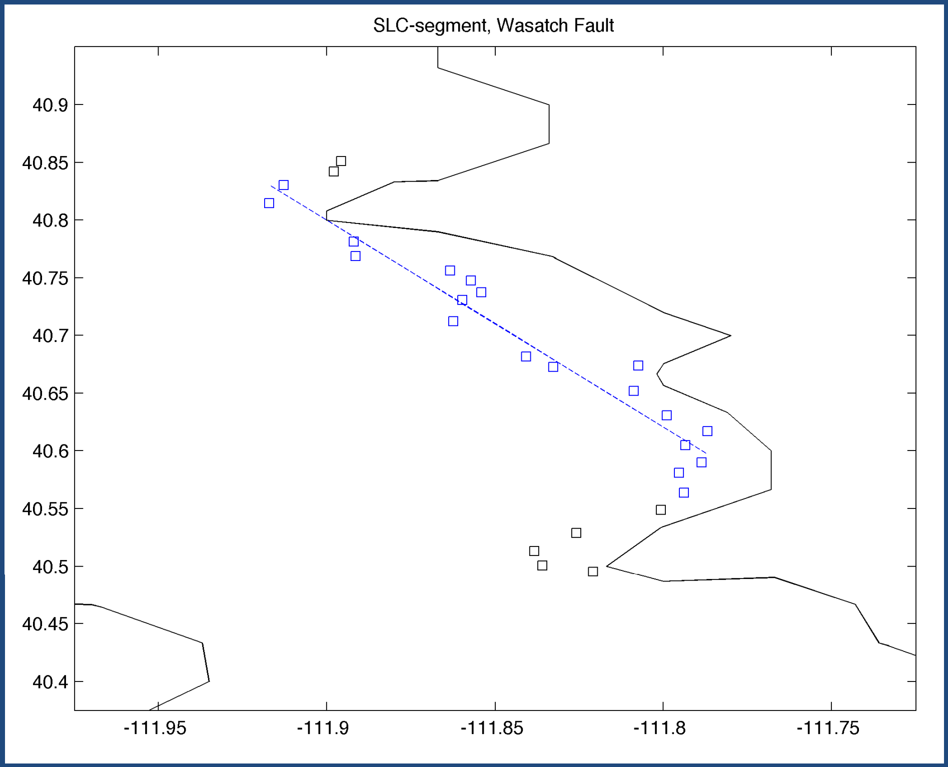
Outline

- Kinematic fault model
  - Geometry
  - Fault parameters
- Material model
  - Reference model
  - Perturbed models
- Wave propagation
- Ground motion results
- Preliminary conclusions and suggestions
- Future plans
  - Low-frequency (<1 Hz)
  - High-frequency (<10 Hz)



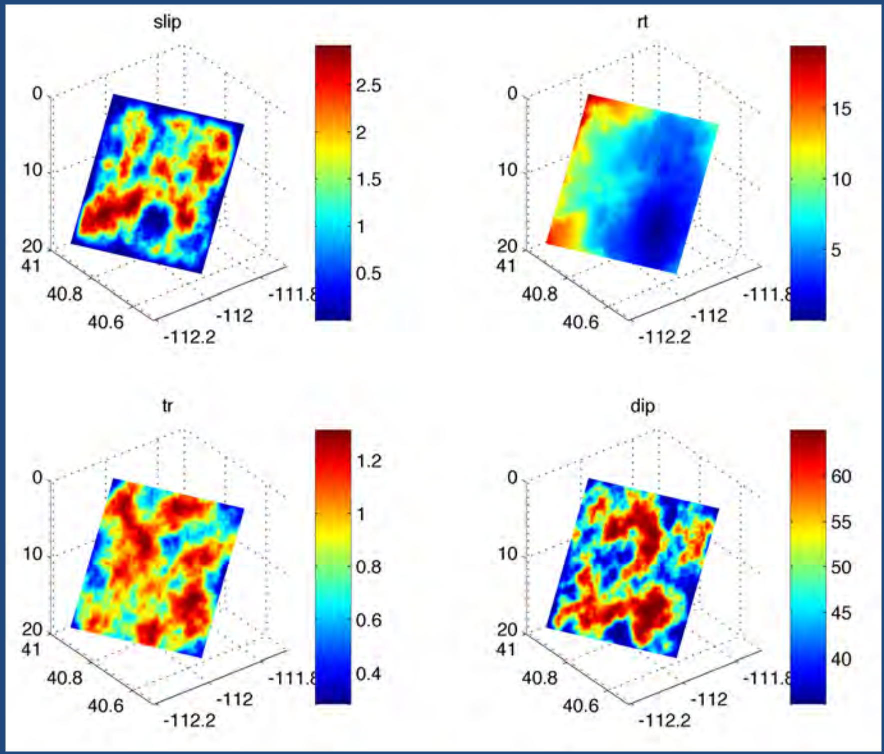
Fault model - geometry

- Planar fault model
  - Fit segment through NSHM fault sources (Salt Lake City segment, Wasatch fault)
  - 50º dip
- Dimensions consistent with Wells and Coppersmith (1994)
  - 45 x 20 km



Fault model – kinematic model parameters

- Hypocenter at 10 km along-strike, 15 km down-dip
- 10^o uncertainties in strike, dip and rake
- 1-D velocity profile from UUSS
- Correlation lengths for slip distribution at high end of fit values for M7 event (Mai&Beroza, 2002) resulting in large coherent patches and increased ground motions.

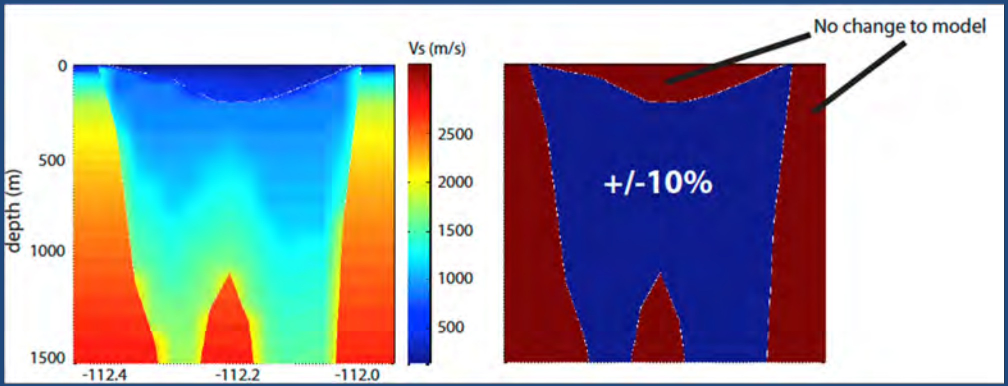


Parameter	Value	References
Mw	7	
V_r	2.8	
f_c	0.075	(Allmann&Shearer, 2009)
C_X/C_Y	20, 10	(Mai&Beroza, 2002)

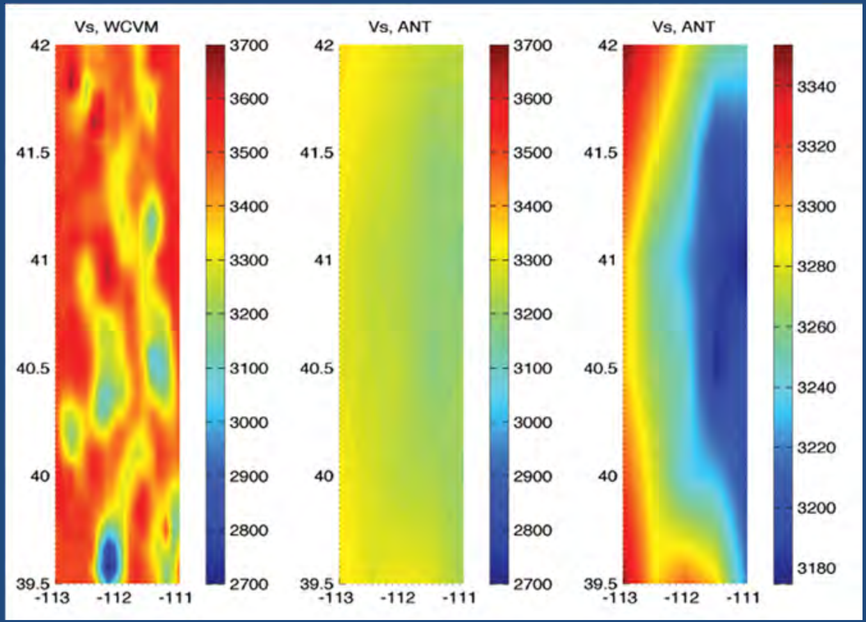
Material models

- Reference model: WCVM, with data kriging above R1.
- Perturbed models:
  - Motivation for testing perturbed models is similar misfit values obtained for these models from regional earthquake simulations
  - Increase deep basin (R1-R3 volume) velocity (+10%)
  - Decrease deep basin velocity (-10%)
  - Regional model -> V_S model from surface wave tomography

Deep basin: R1-R3 volume



V_S models



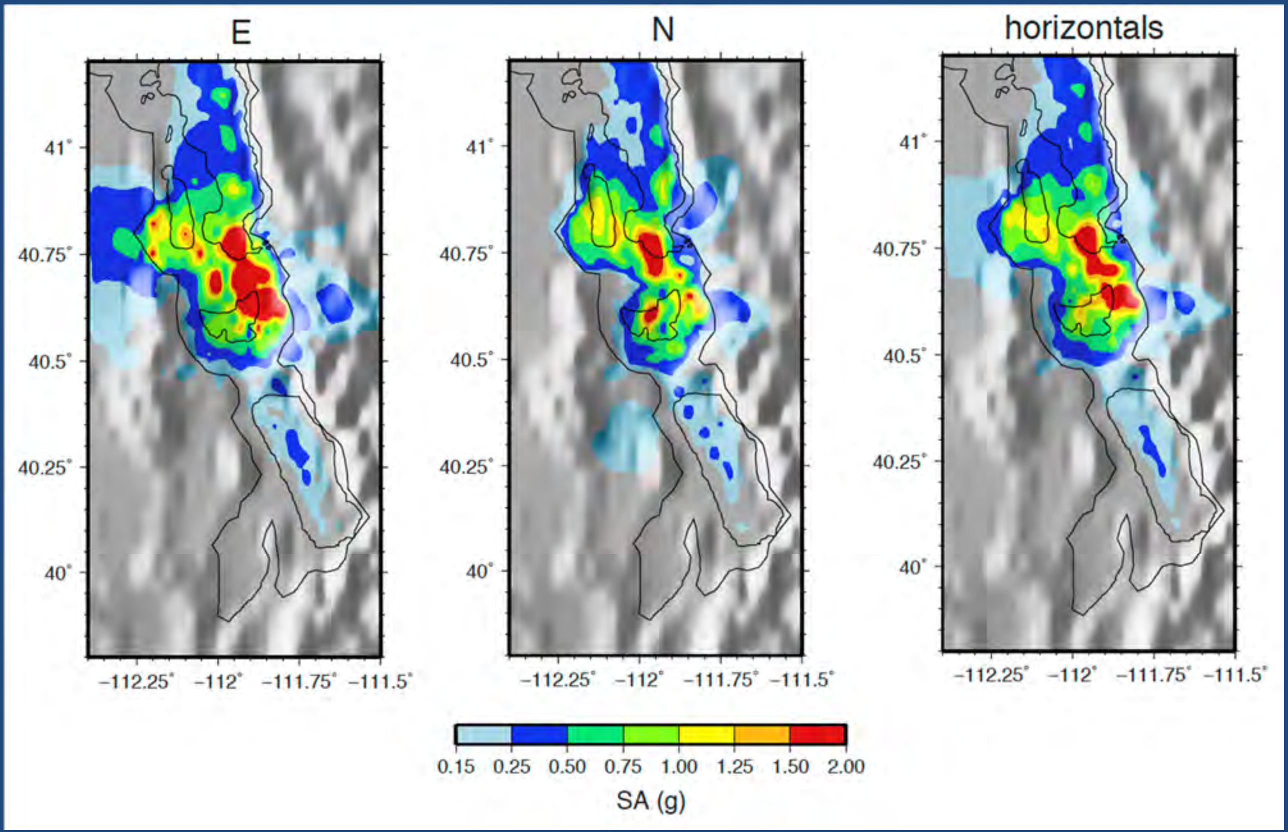
Wave propagation

- Hercules, CMU (Tu et al., 2006) – mesh/partition/solve tool, finite-element
- EQ simulation parameters
  - 1 Hz maximum frequency
  - 200 m/s minimum shear-wave velocity
  - 80 (E-W) x 160 (N-S) km region

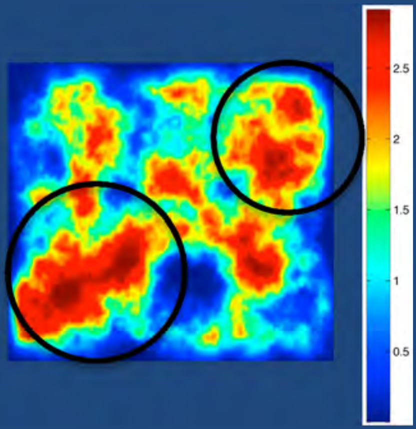
from Tu et al. (2006)

Figure 2: **Online, end-to-end simulation pipeline.**

Preliminary ground motion results – 2 s, SA

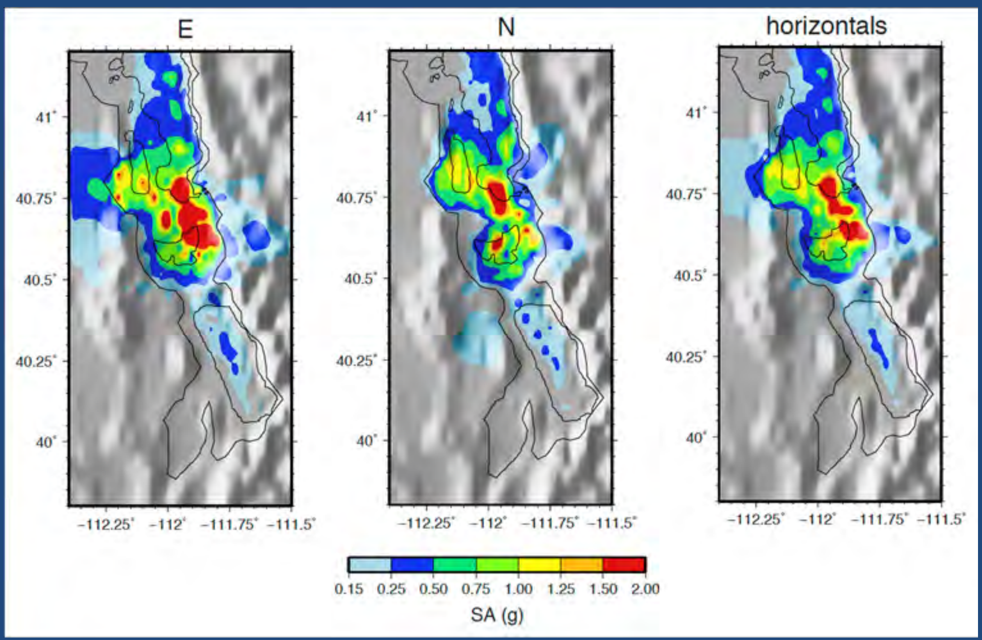


- Highest ground motions along/near surface trace of fault.
- Largest motions within basin, regions of thick sediments.
- Correlations between high ground motions and large, coherent slip patches in the fault model

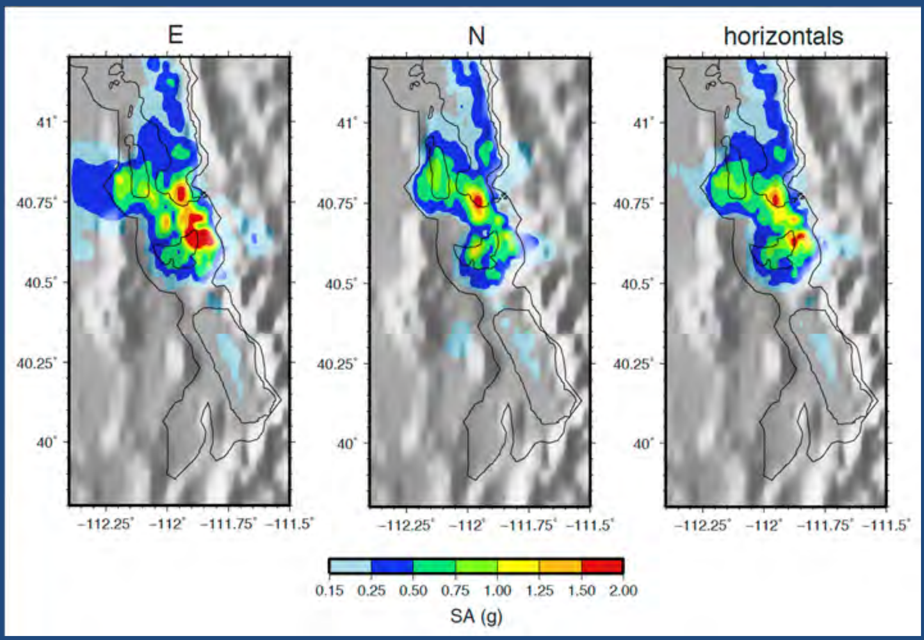


Comparison of preliminary ground motion results – 2 and 5 s, SA

2 s

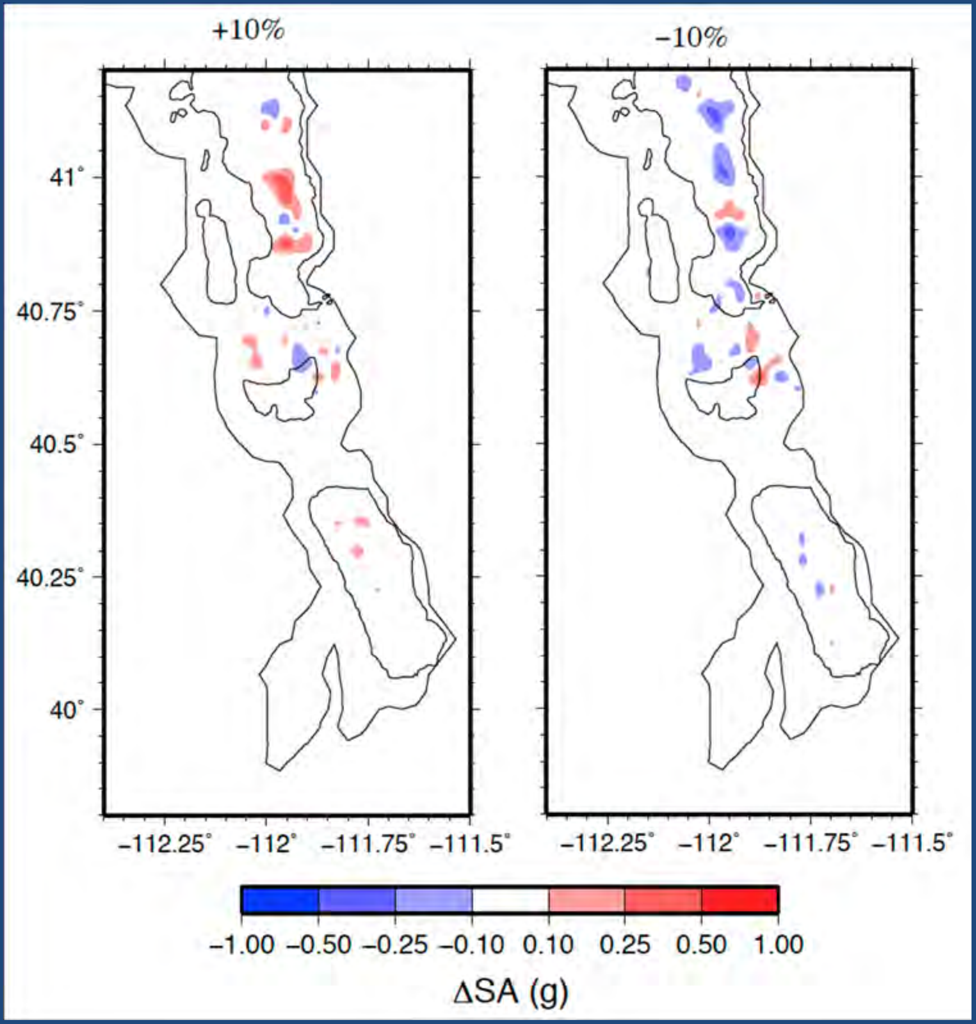


5 s



Effect velocity perturbations on WCVM: R1-R3 volume perturbations

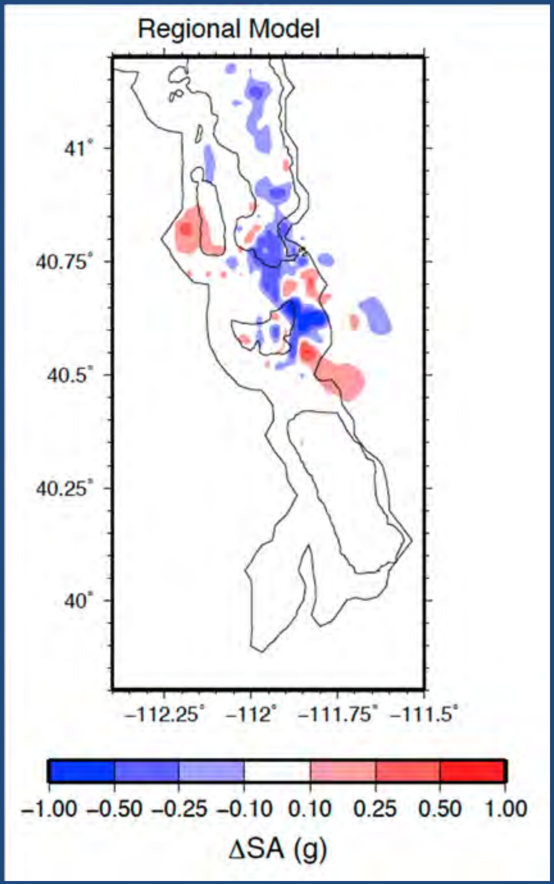
2 s, SA, E-comp



- Spatial aliasing in data contributes to alternating difference patterns.
- Similar changes in E- and N-components; 5 s changes less than 2 s changes
- Velocity perturbations to deep basin structure cause ground motion changes of 0.5 g.
- Increasing deep basin velocity (generally) increases ground motions
- Decreasing velocities decreases ground motions
- Regions of largest ground motion changes above deepest sediments and outside region of the fault – source predominantly affects ground motions above fault plane
-

Effect velocity perturbations on WCVM: regional model perturbations

2 s, SA, E-comp



- Direct comparisons for regional model perturbations not straightforward because velocity changes in the regional model cause changes in the velocity structure at location of source in wave propagation code.
- Net effect of replacing regional model is to decrease seismic moment; however, still see localized increases in ground motion. Effectively changing source model.
- Velocity perturbations to regional model cause ground motion changes greater than 0.5 g.
- Greatest ground motion changes occur in the source region – above and near to fault plane.
- High lateral heterogeneity in the regional model presumably poorly constrained but causes strong effects on source zone ground motions

Preliminary conclusions and suggestions for quantifying ground motions

- Strong effect of kinematic fault model on ground motions; correlations between patches of large slip and high ground motions
  - Representative sampling of fault source parameters to quantify parametric uncertainty of source models.
- Large effects of velocity structure perturbations on ground motions (~0.5g). Greatest effects on ground motions caused by: (1) basin velocity structure away from source and (2) regional model structure near source model.
  - Quantify uncertainties in velocity structure for effects on ground motion uncertainties.

Future plans

- Low frequency synthetics
  - Realistic fault geometry (w/ Y. Zeng)
  - Set kinematic models to sample fault parameters (w/ Y. Zeng, S. Hartzell)
    - Effect of varying fault parameters (e.g., hypocenter, slip distribution, rupture velocity)
    - Different methods for calculating slip distributions (e.g., Hartzell et al., 2011)
- High-frequency synthetics (w/ Y. Zeng, S. Hartzell)
  - High frequency 1-D synthetics
  - Nonlinear effects

3D Ground Motion Linear and Nonlinear Simulations

Salt Lake City Basin

D. Restrepo, R. Taborda, and J. Bielak

The QUAKE Group

at Carnegie Mellon University

Department of Civil & Environmental Engineering

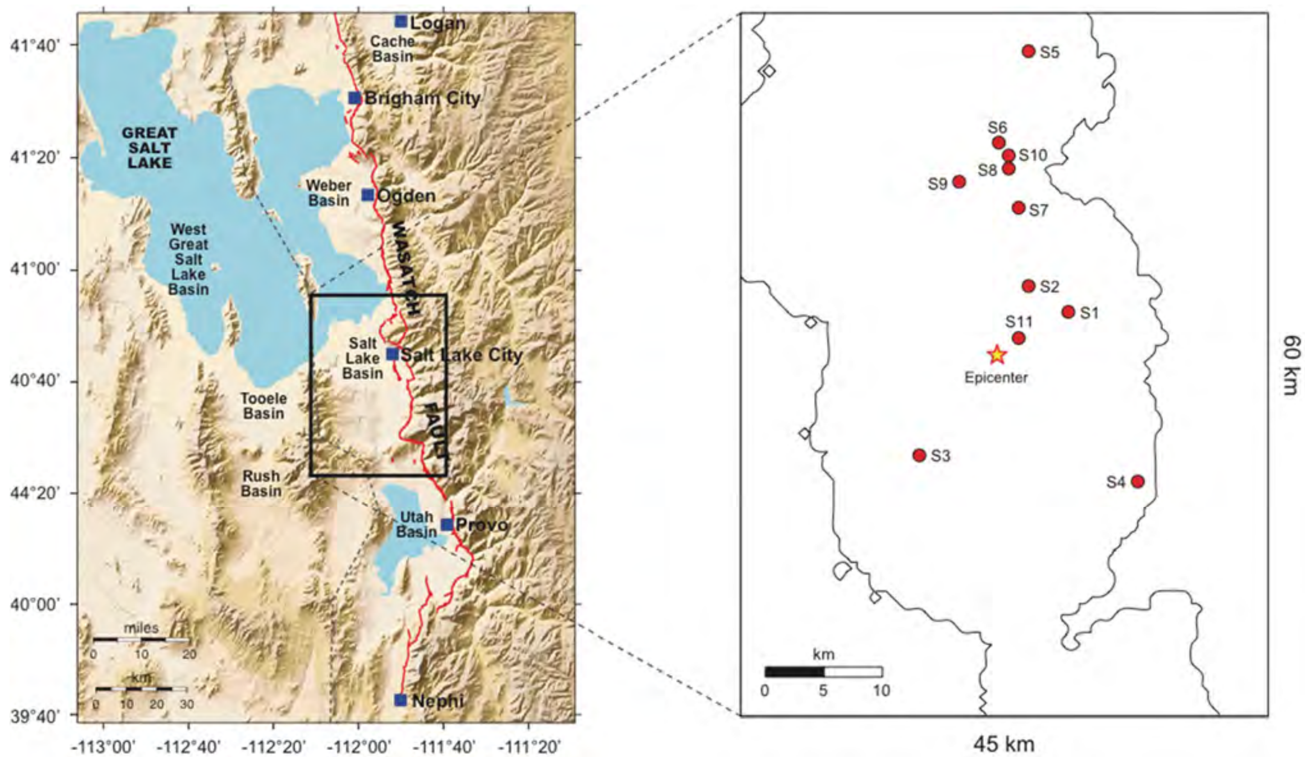
Computational Seismology Laboratory

USGS

science for a changing world

Region of Interest & Simulation Parameters

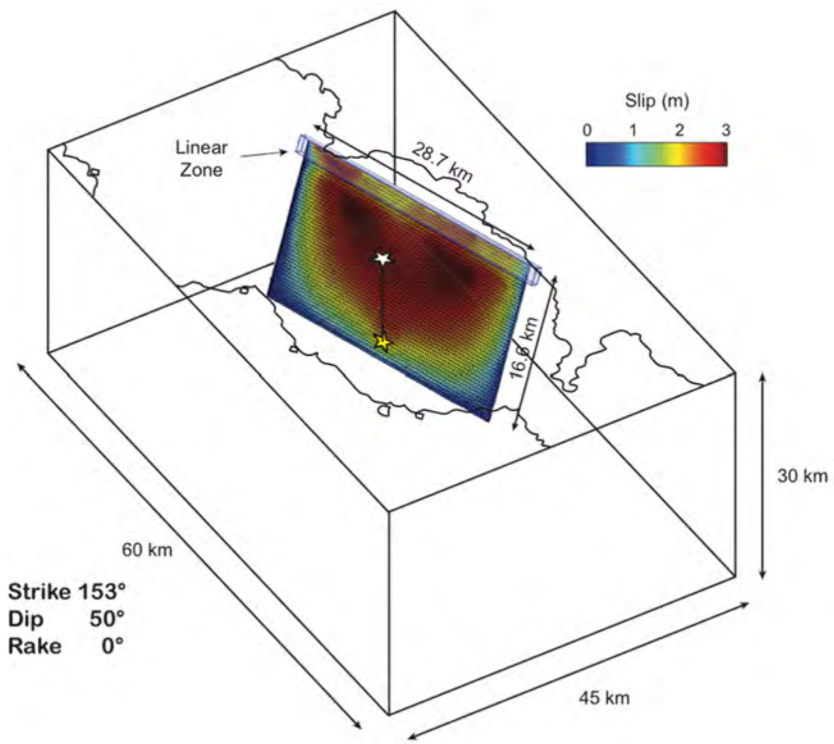
- M_w 6.8 scenario earthquake (Liu and Archuleta, 2011).
- Simulation time 75s. Δt=0.005s for the linear simulation, Δt = 0.00065s nonlinear case.
- Total mesh 18 million elements
- Vs min=200 m/s
- fmax 1Hz
- 8 points per wavelength.

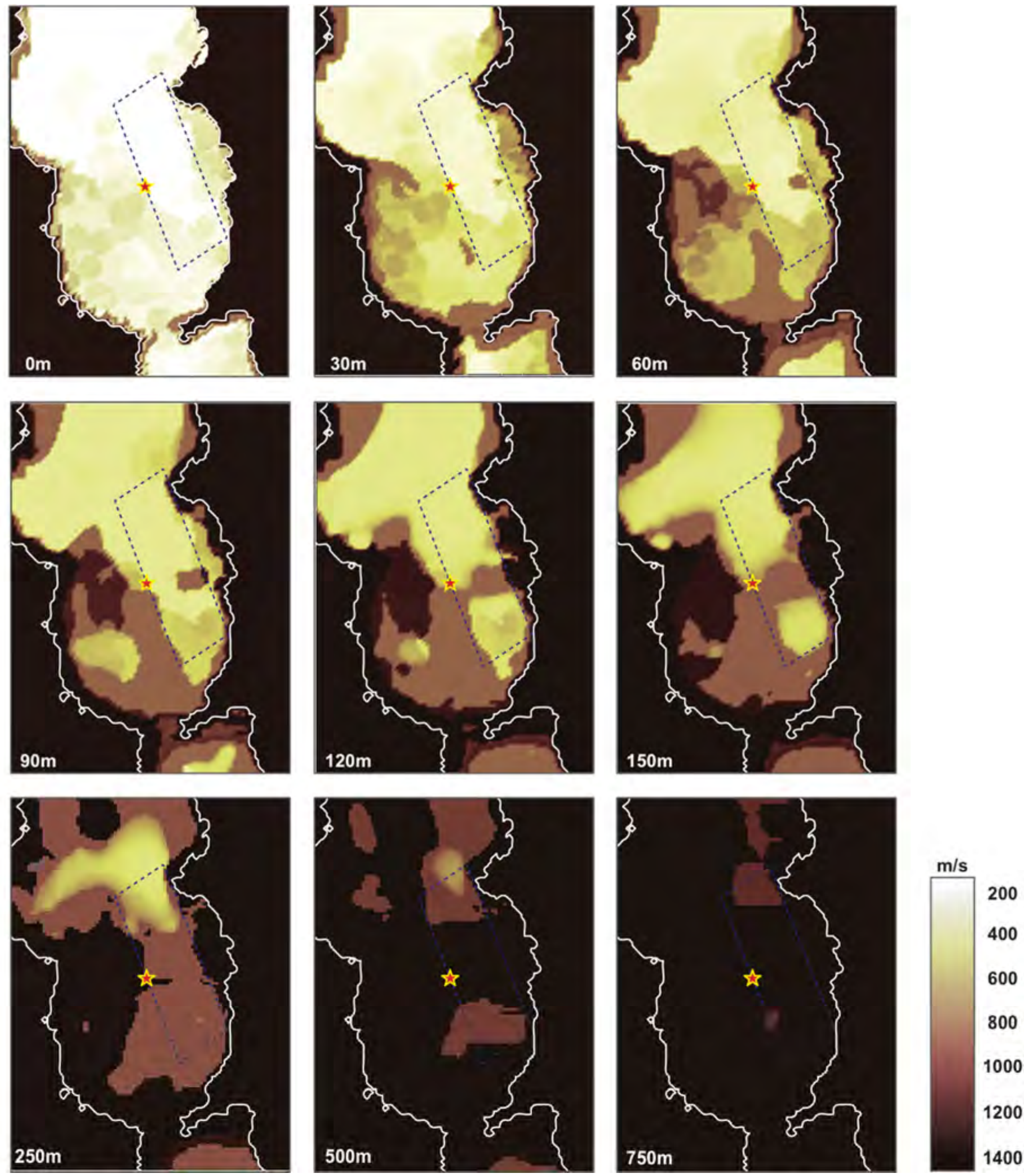


Nonlinear Analysis:

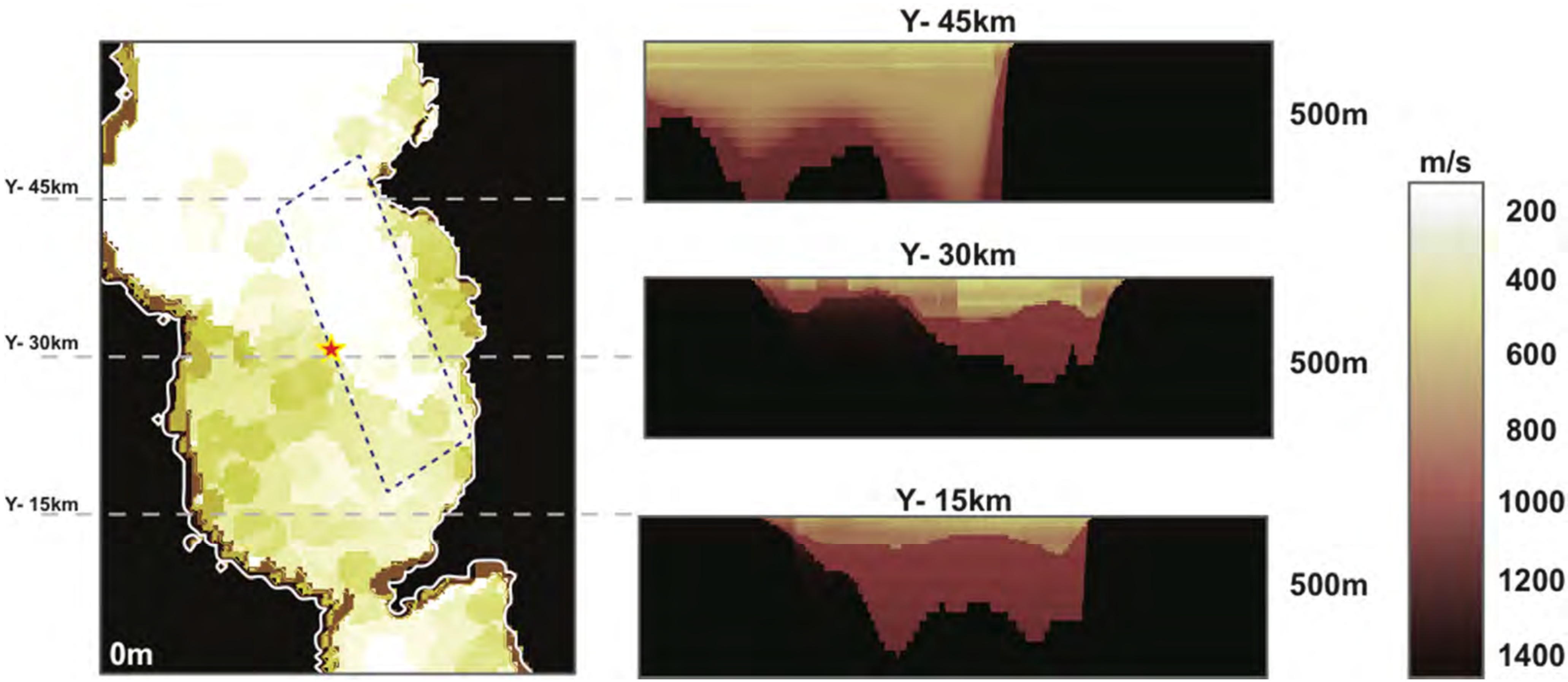
- Soft soils with Vs $\leq$ 500 m/s were allowed to behave plastically.
- Material idealized to follow the von Mises J2 yield criterion.
- Yielding conditions based on the stress (J2) histories obtained during a reference linear simulation. On average, the yielding limits used were of about 25 percent the maximum J2 values registered during the linear simulation.

Shear Wave Velocities and Fault Location

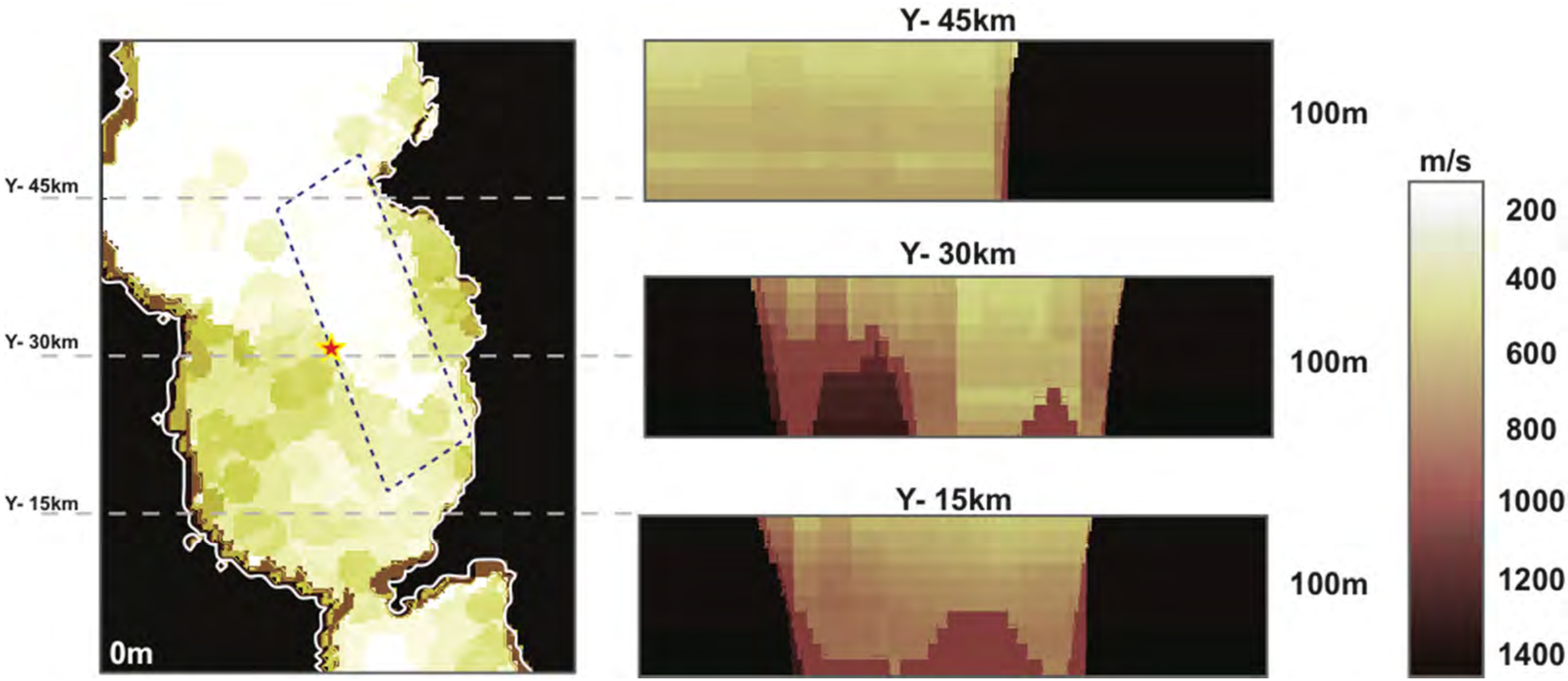




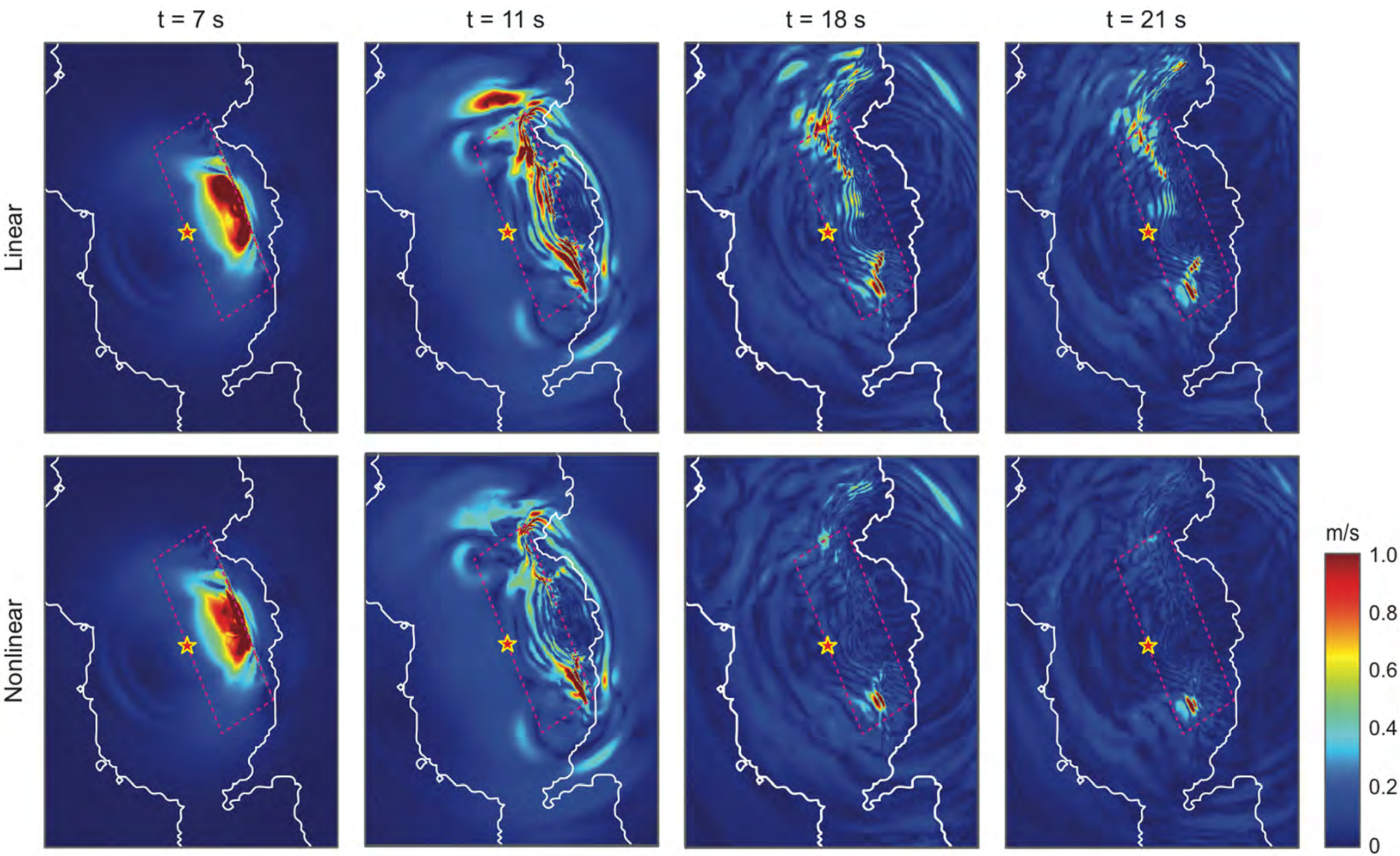
Basin Vertical Cross-Sections Depth 500 m



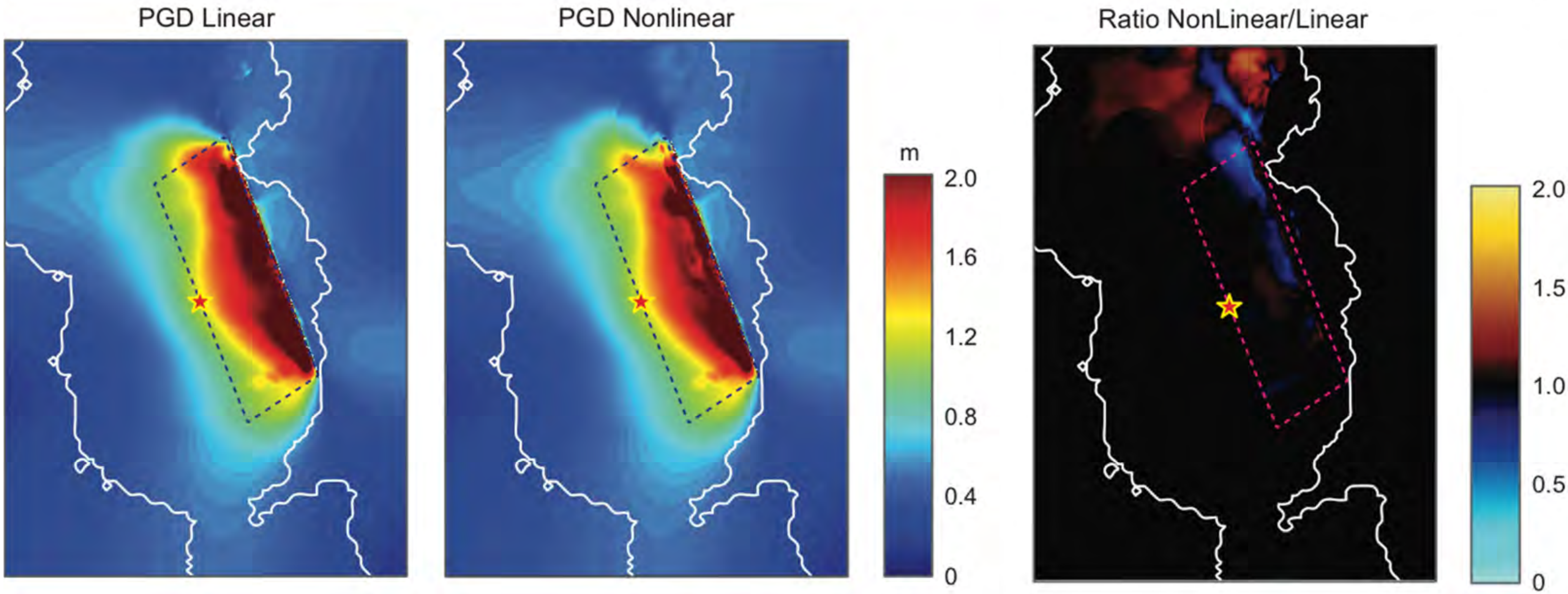
Basin Vertical Cross-Sections Depth 100m



Horizontal Velocity Snapshots

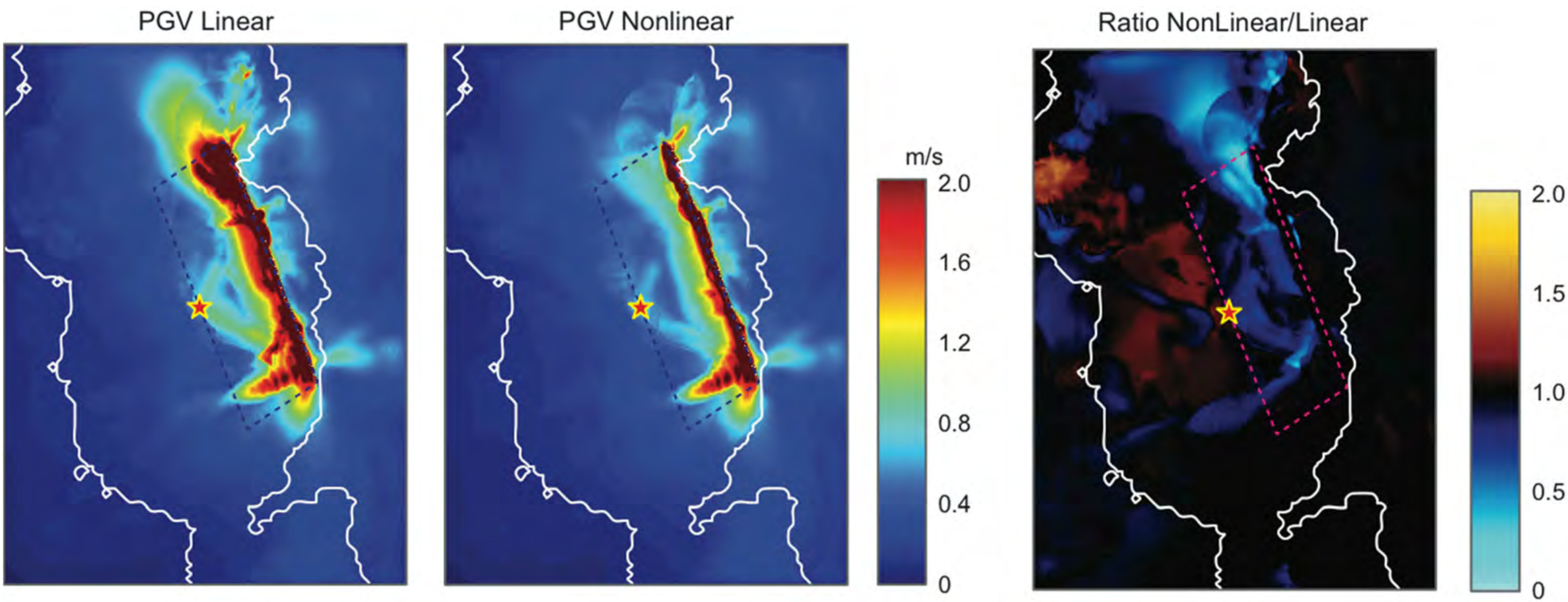


Peak Ground Displacements



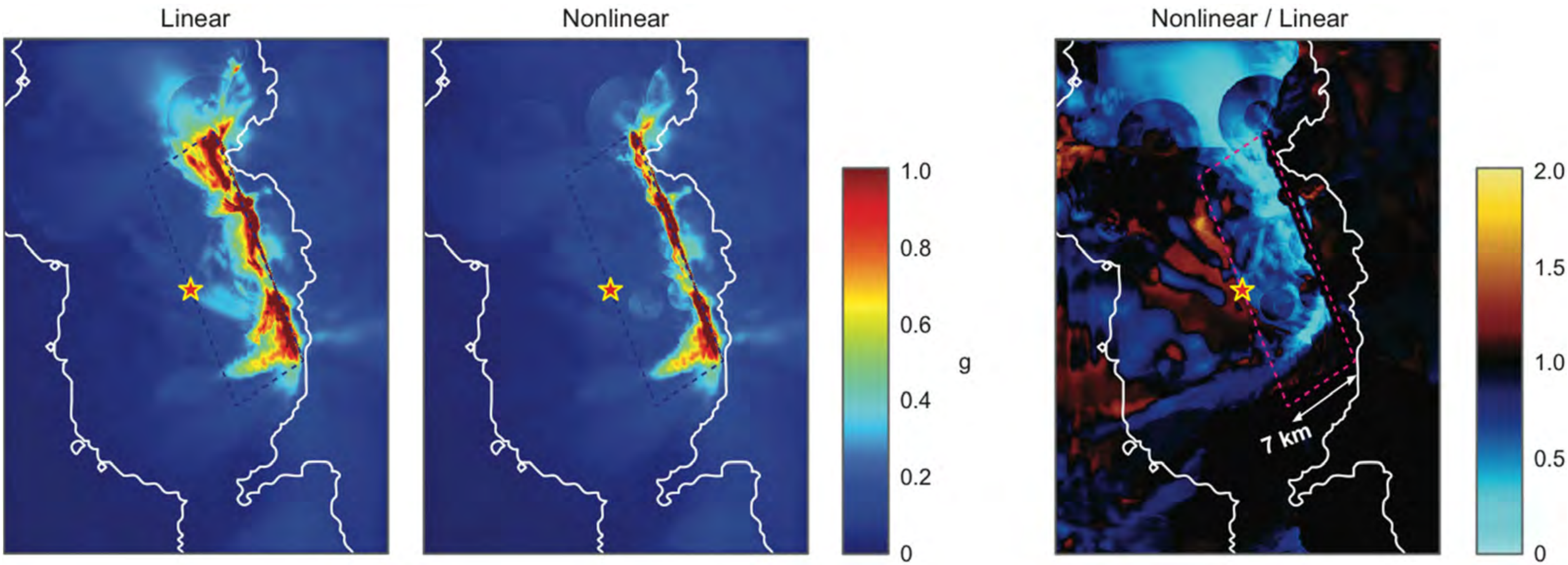
- Peak distribution similar to slip distribution on the fault

Peak Ground Velocity



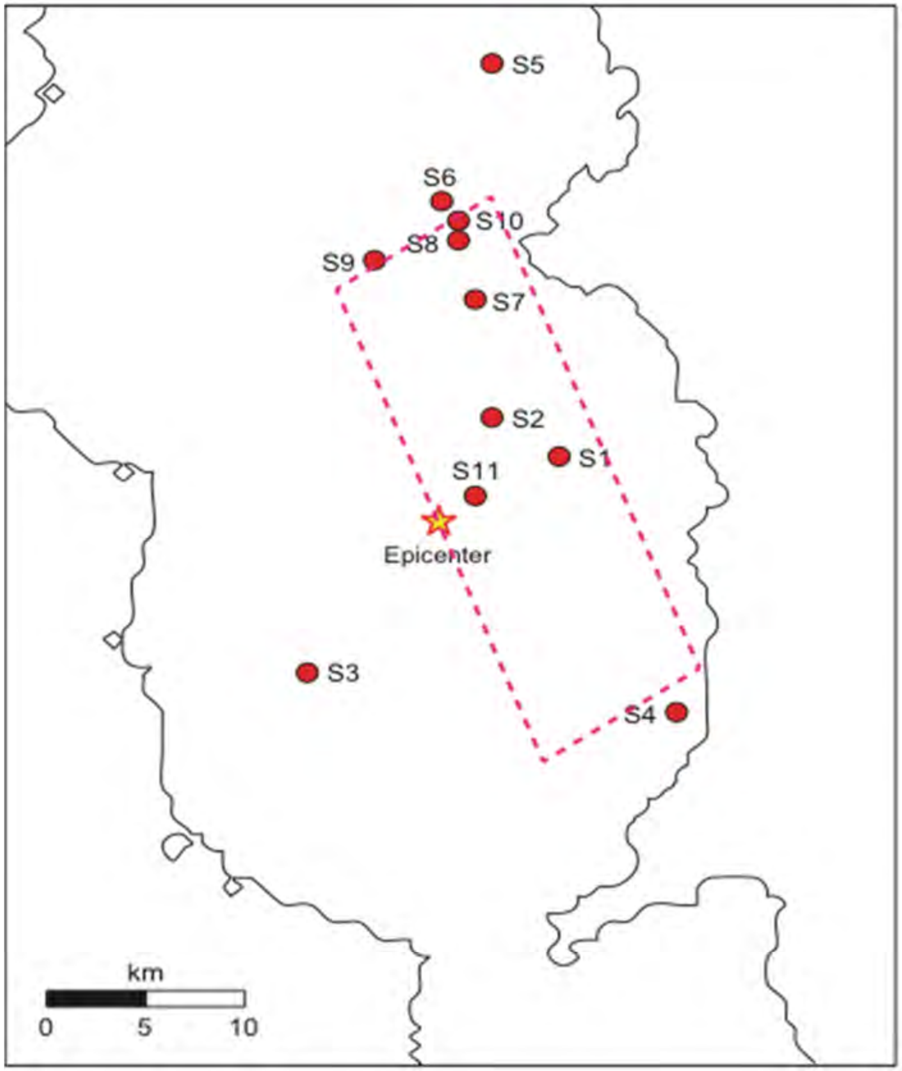
- No evidence of strong basin effects

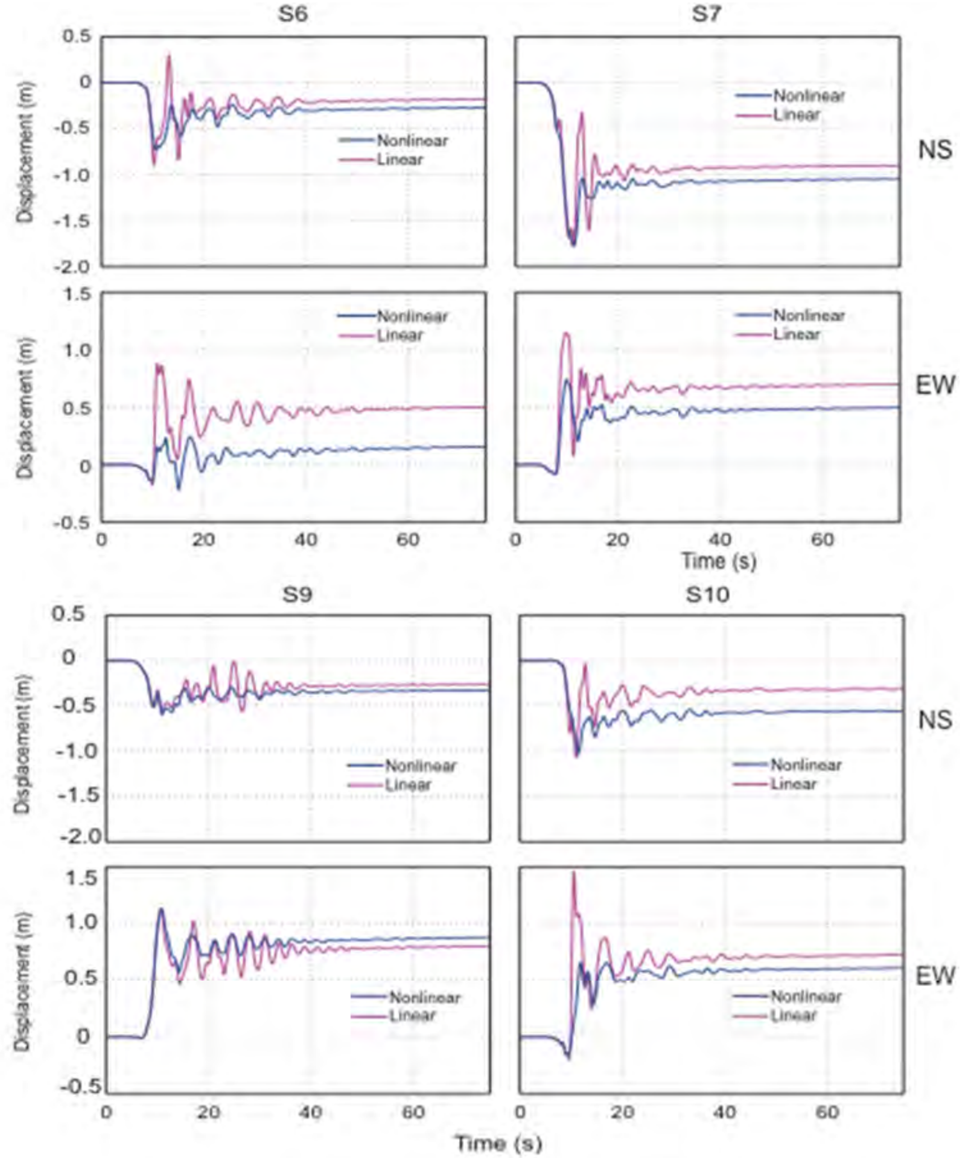
Peak Ground Acceleration

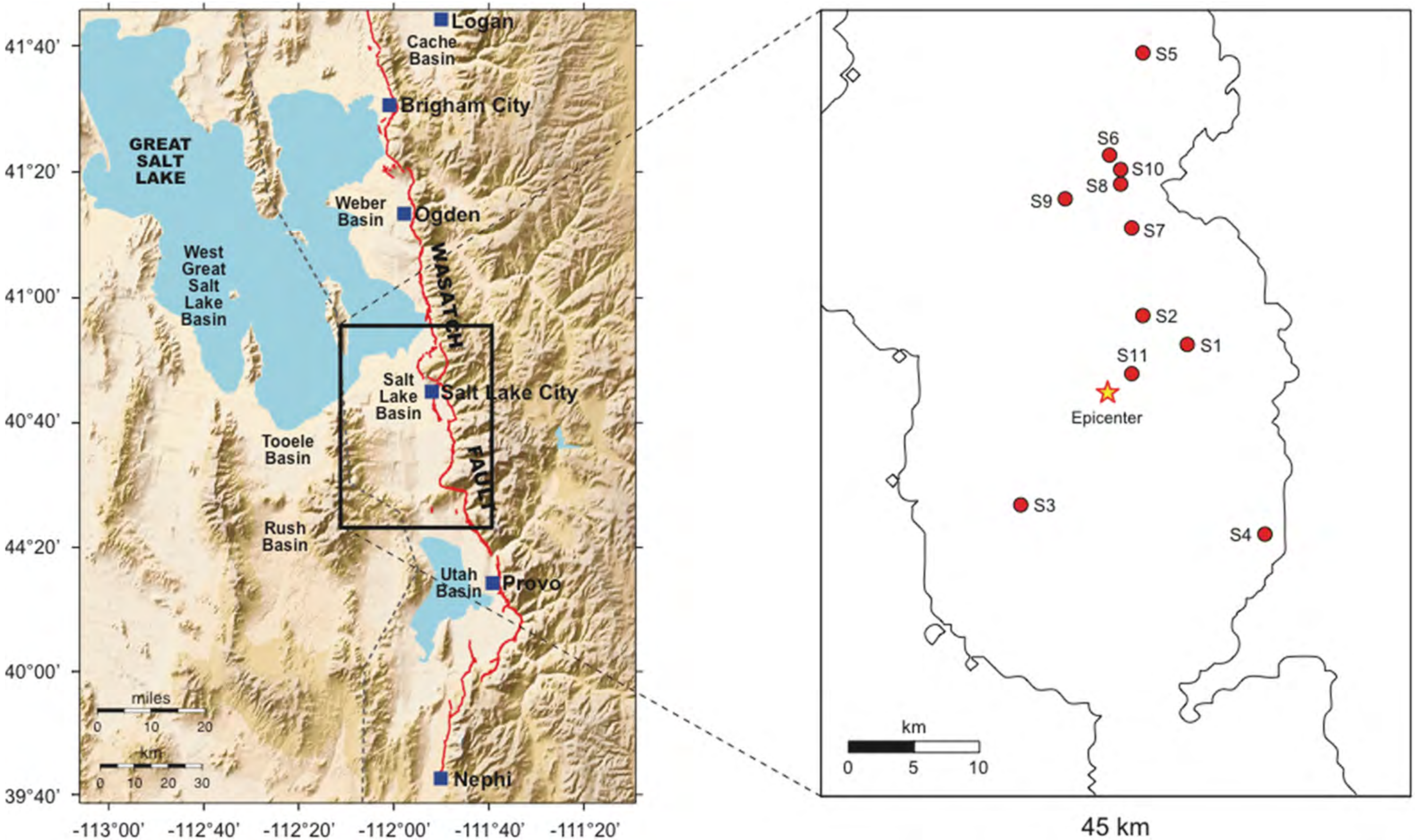


- Maxima in both cases concentrate near the fault line and above the fault's plane projection on the surface.
- The ratio shows how in many areas the nonlinear case has lower values of peak acceleration than the linear case, though there are areas of amplification as well. Amplification occurs only in regions with small ground motion.

Near–Fault Displacement





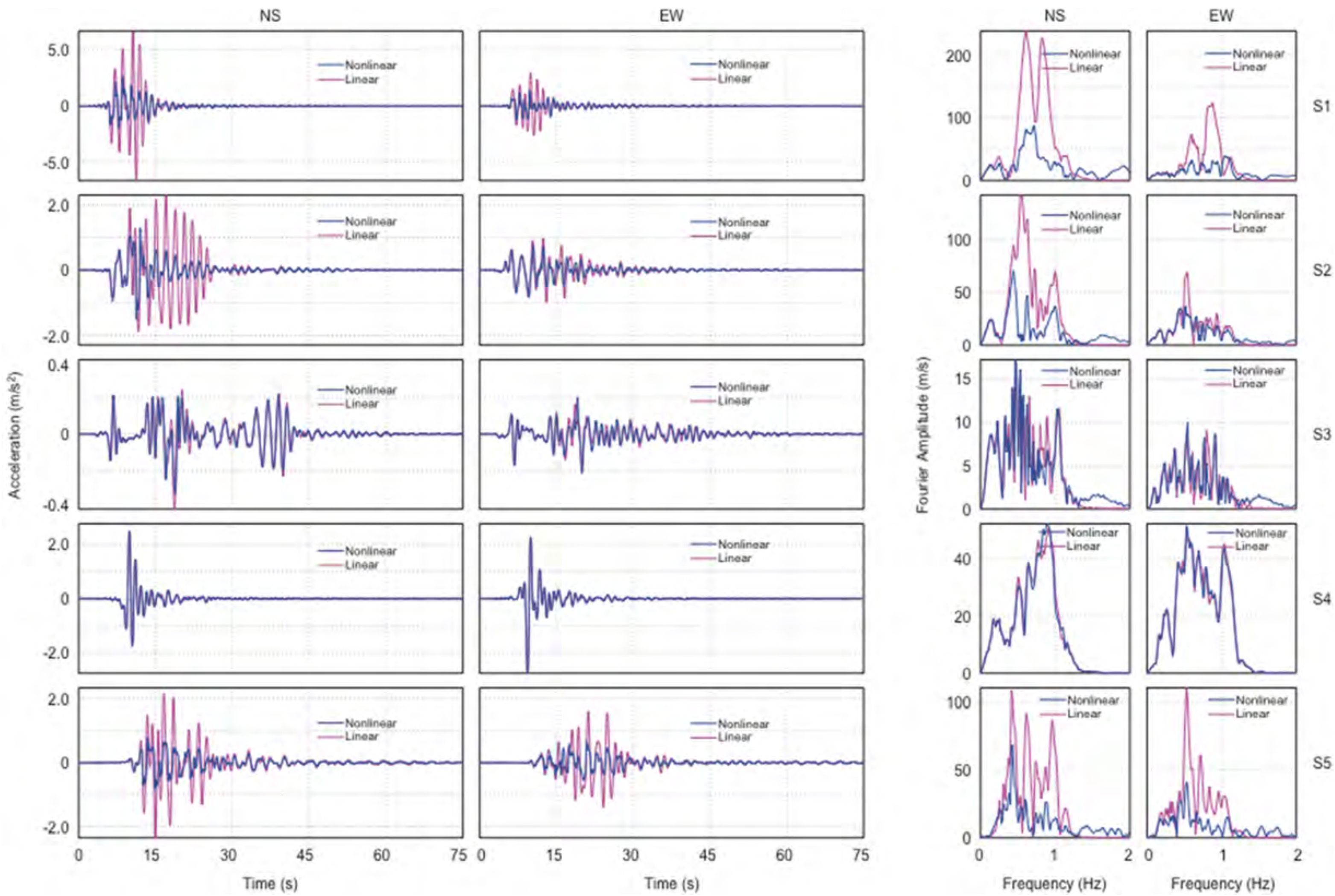


Logan
Cache Basin
Brigham City
GREAT SALT LAKE
Weber Basin
Ogden
WASATCH
West Great Salt Lake Basin
Salt Lake Basin
Salt Lake City
FAULT
Tooele Basin
Rush Basin
Utah Basin
Provo
Nephi
miles
0 10 20
km
0 10 20 30
41°40'
41°20'
41°00'
40°40'
44°20'
40°00'
39°40'
-113°00'
-112°40'
-112°20'
-112°00'
-111°40'
-111°20'
S5
S6
S10
S8
S9
S7
S2
S1
S11
Epicenter
S3
S4
km
0 5 10
45 km

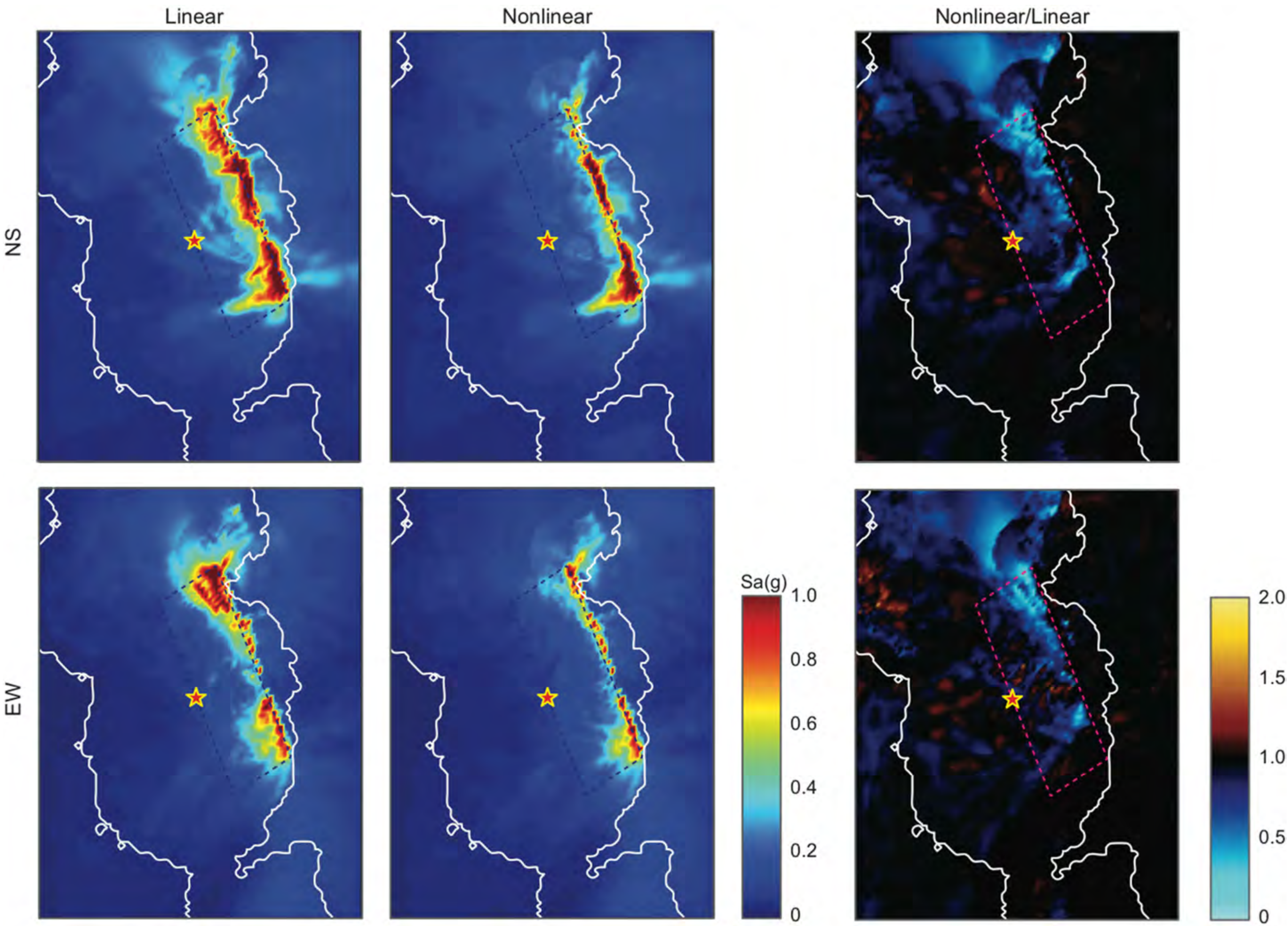
Acceleration

• Nonlinear PGA are about 50 percent or smaller than the peak accelerations registered in the linear simulation.

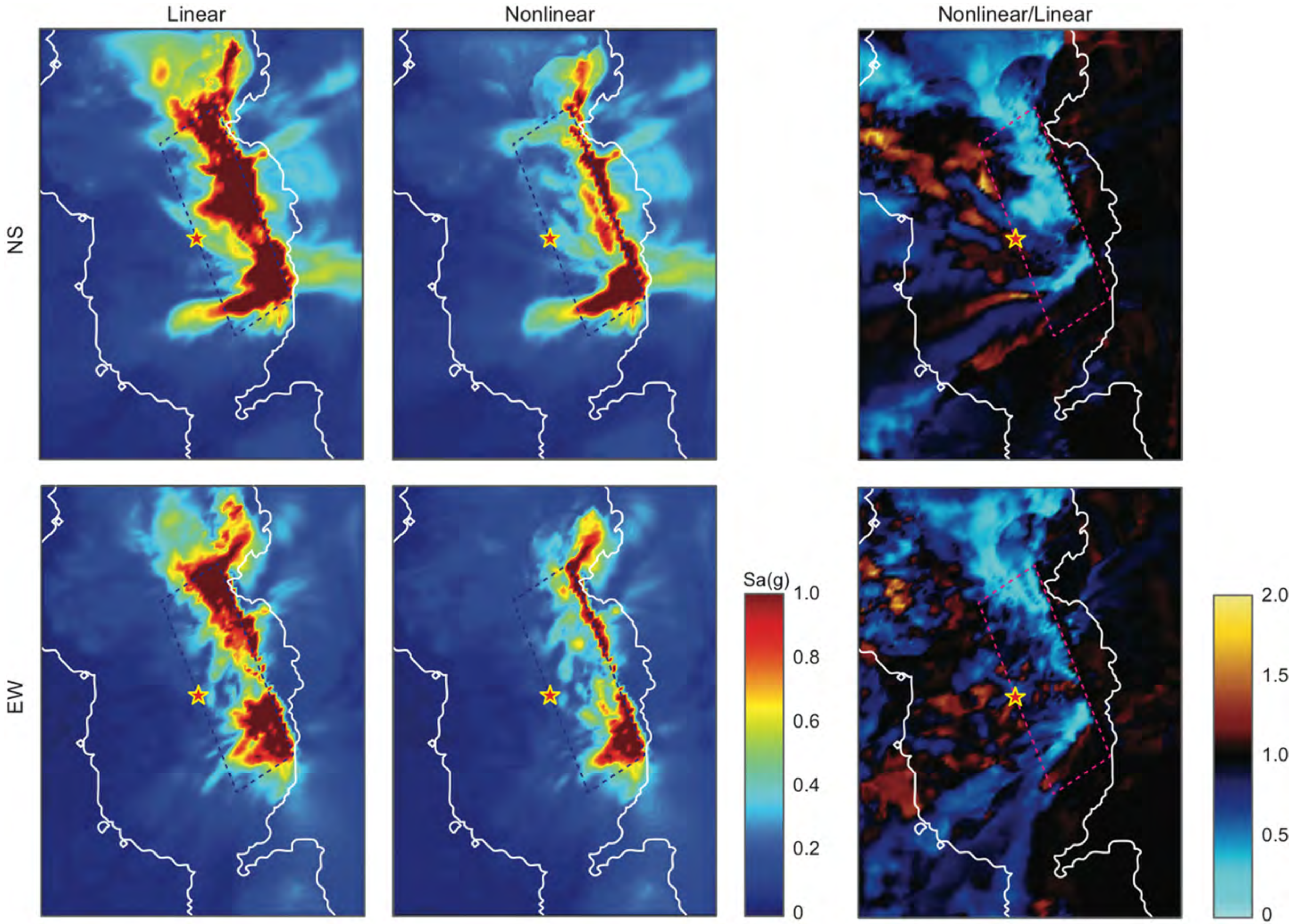
•Station S2 has reductions that are predominant in the NS direction, whereas in S1 and S5 the reductions are of the same order in both components of motion.



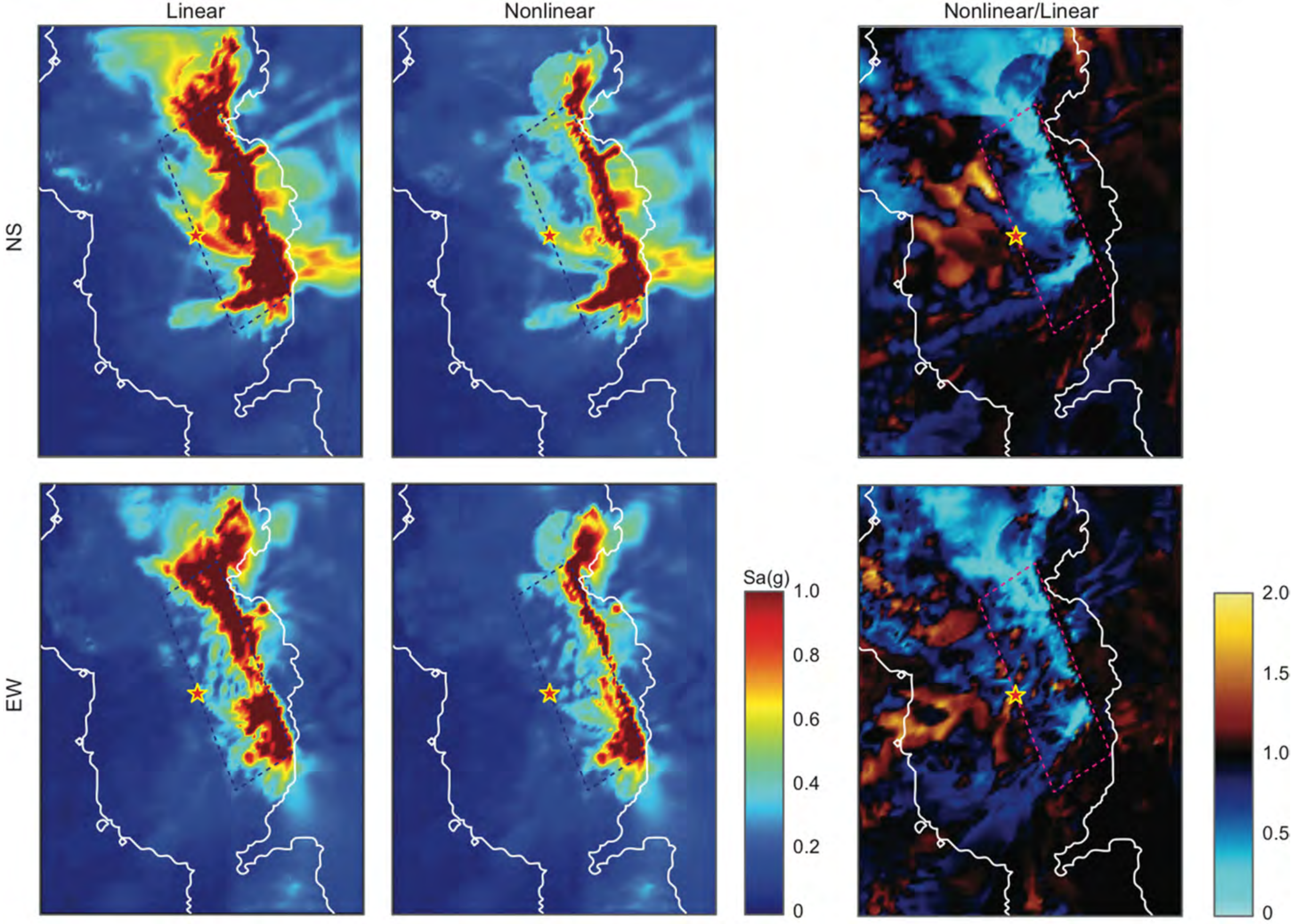
Response Spectra $S_a(g)$, T_e=5s



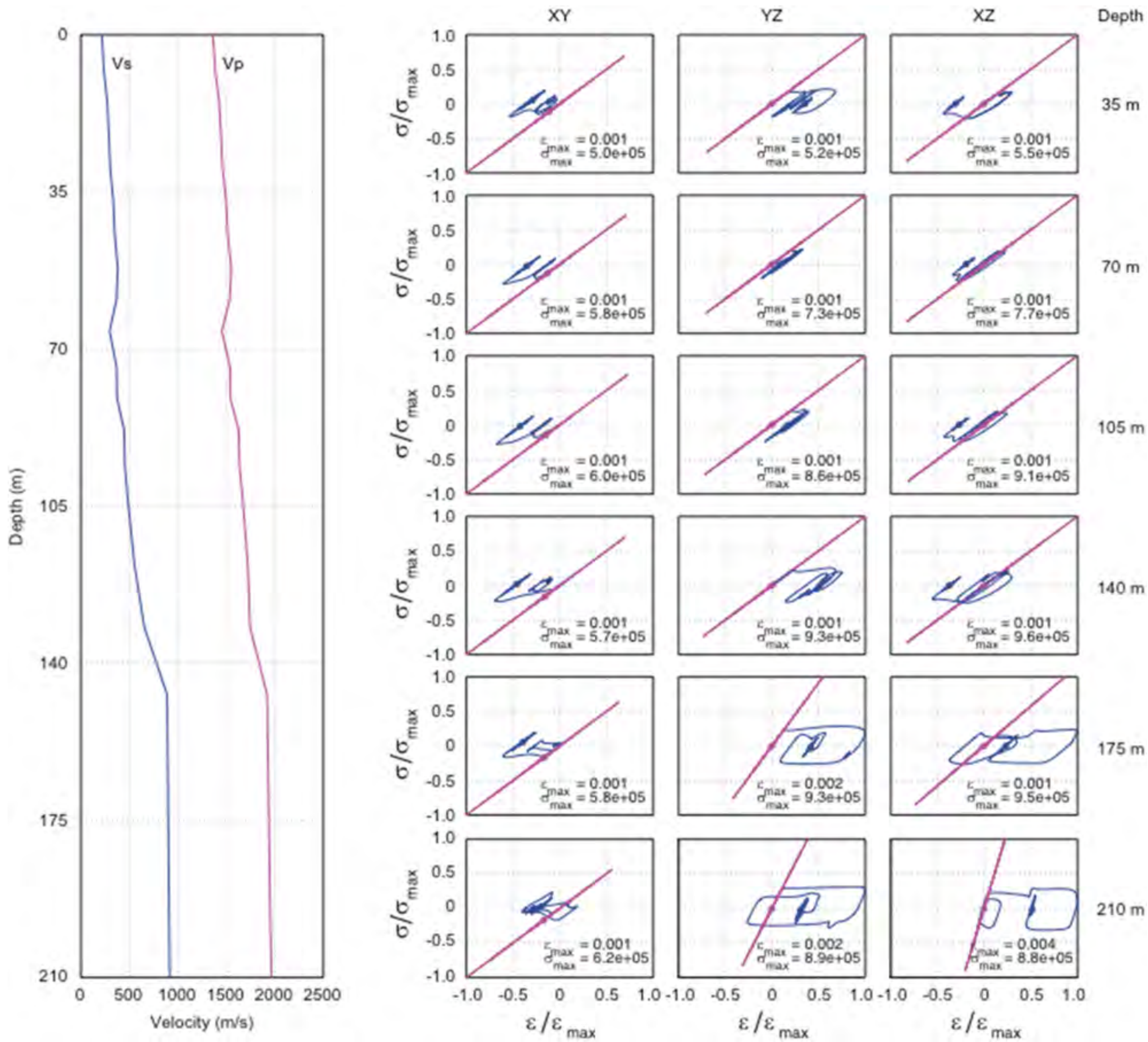
Response Spectra $S_a(g)$, T_e=2s



Response Spectra $S_a(g)$, T_e=1.5s



Borehole: Stress-Strain



Instrumentally Recorded Ground Motion in the Utah Region since 2000
(Work in Progress)

Kris Pankow

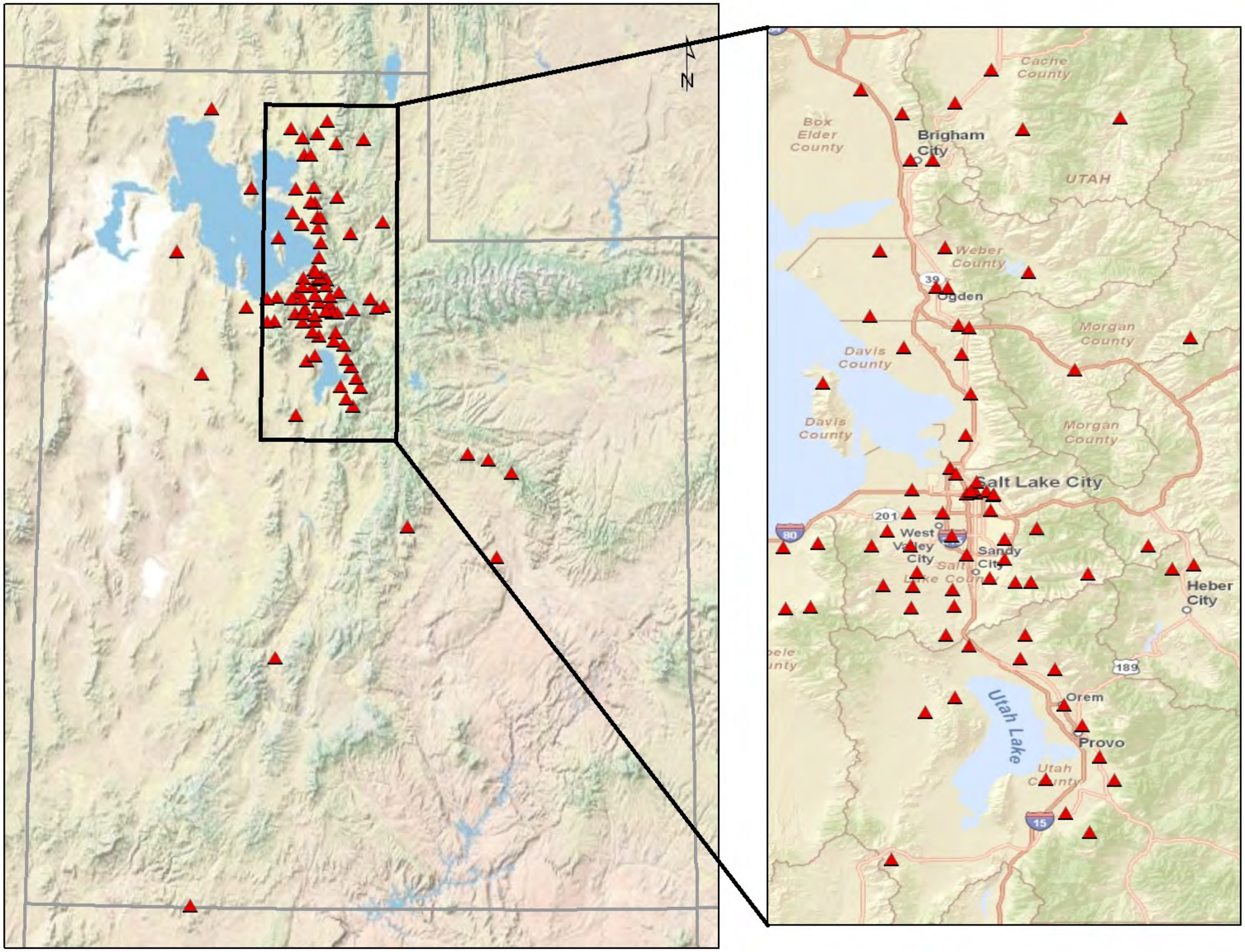
UNIVERSITY OF UTAH
SEISMOGRAPH STATIONS
THE UNIVERSITY OF UTAH

2010 UGS GSWG
Salt Lake City, Utah
February 14, 2012

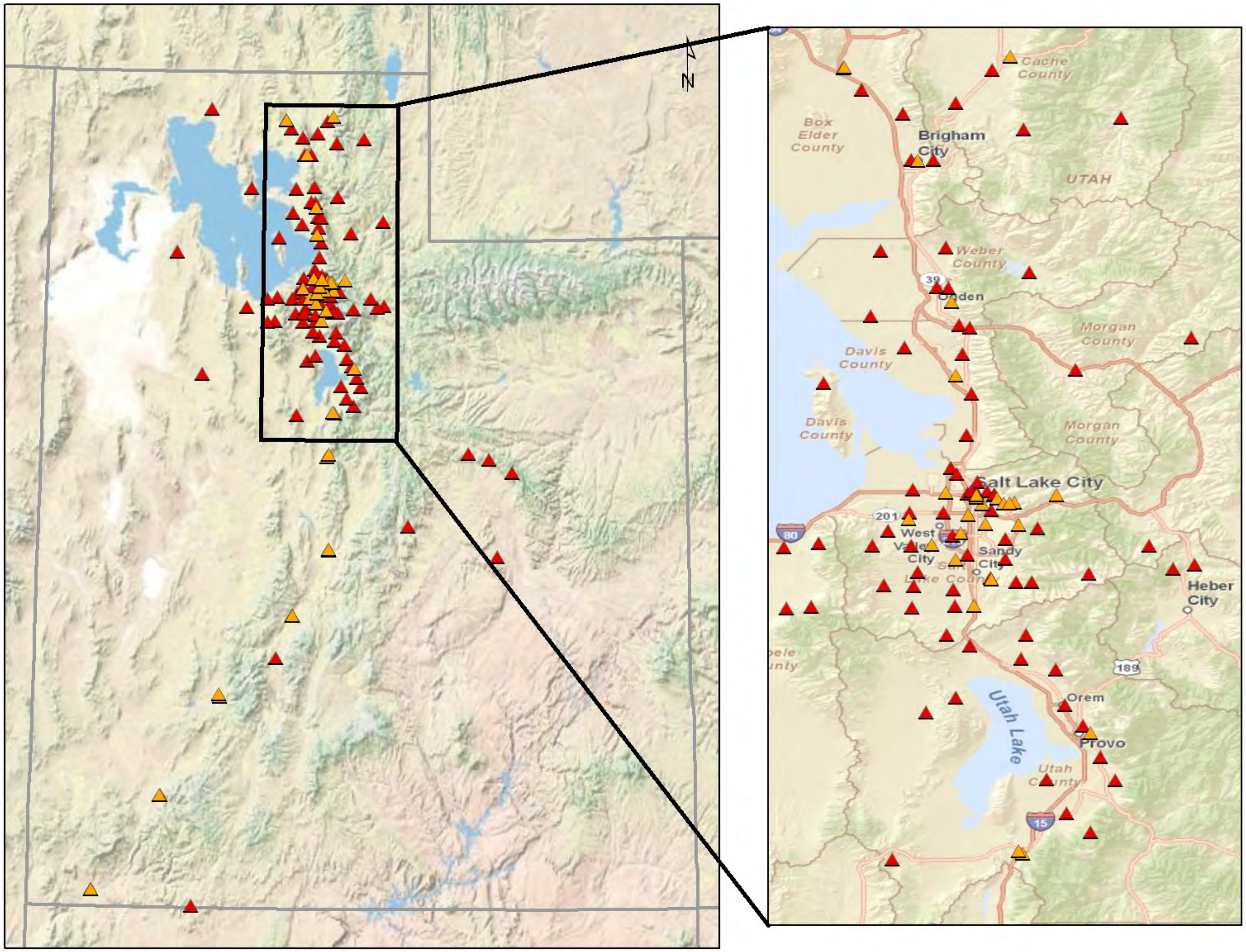
Goals (short- and long-term)

- Measure PGA and PGV for ML ≥ 3 earthquakes within 200 km of Utah network
- Sort by site-class unit
- Compare to published ground-motion equations

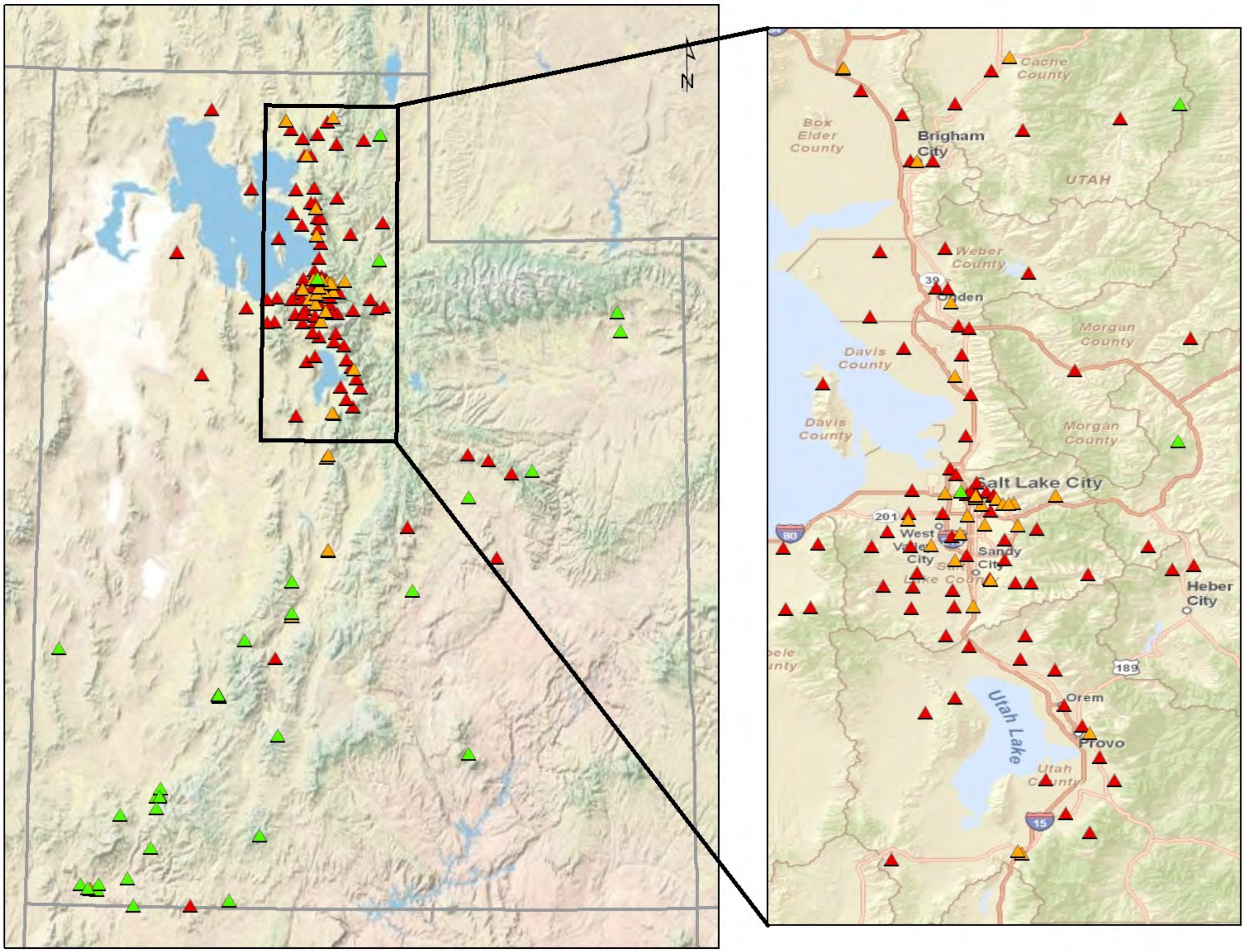
Network 2000-2005



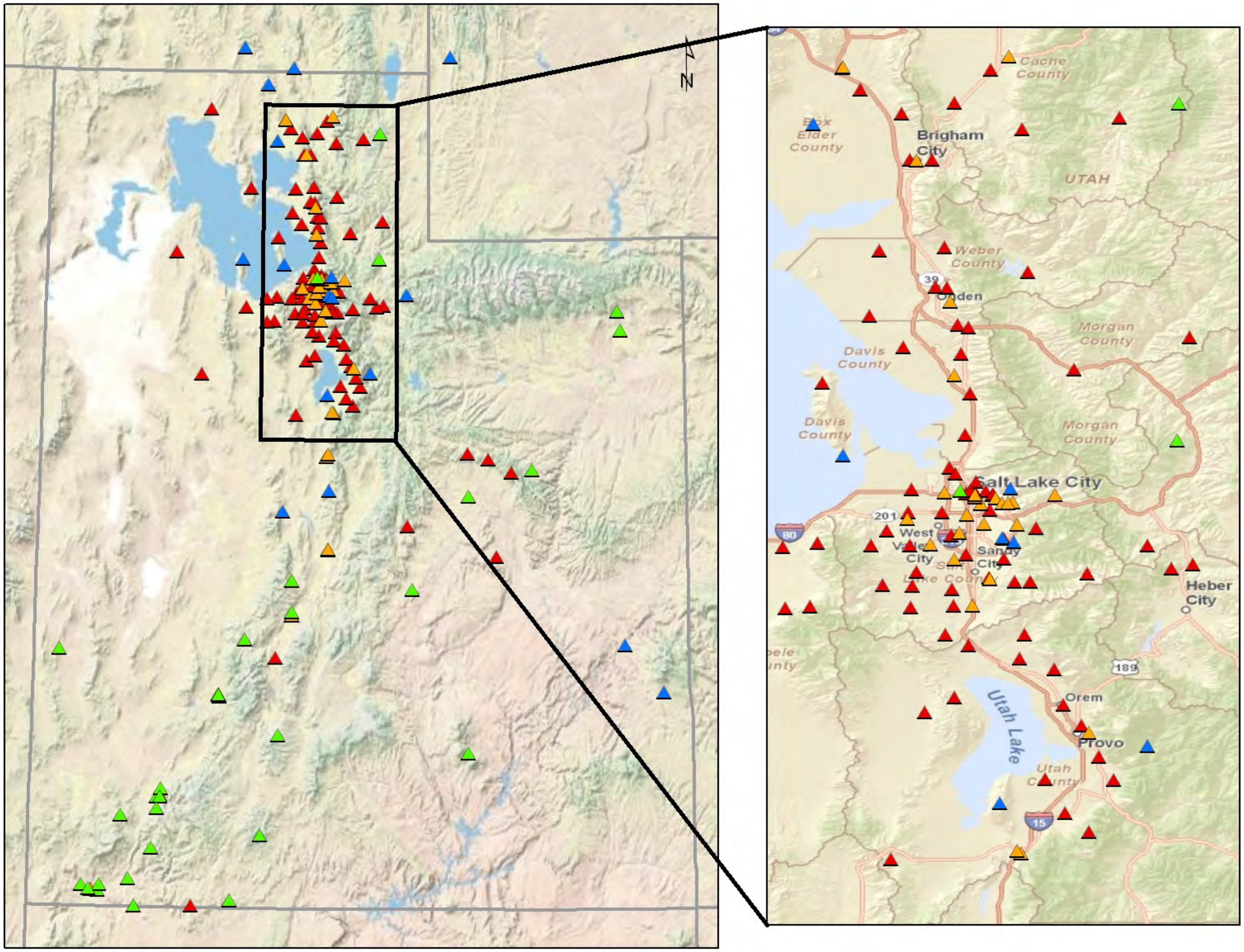
Network 2005 to 2008



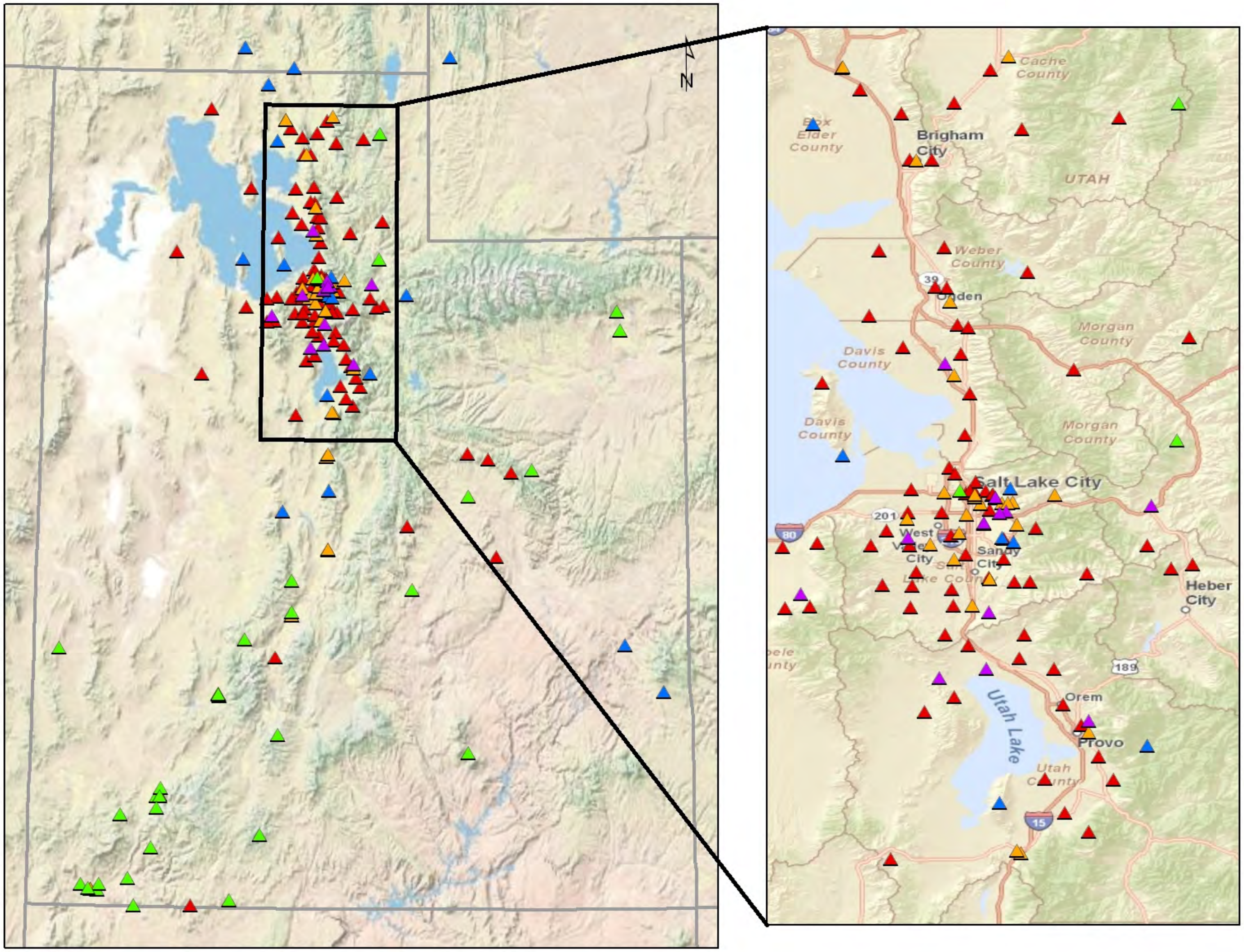
Network 2008 to 2009

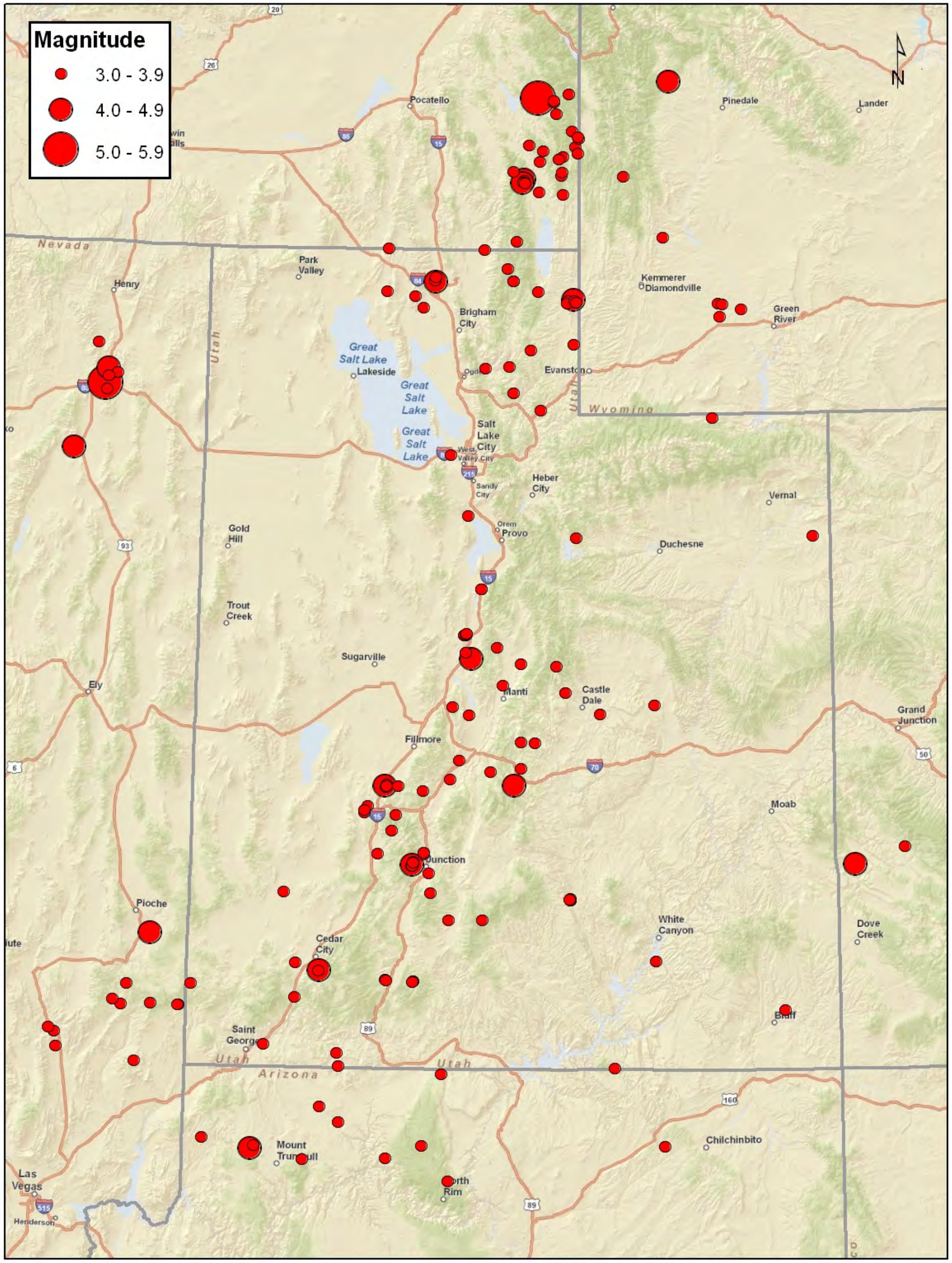


Network 2009 to 2011



NetQuakes 2010 --





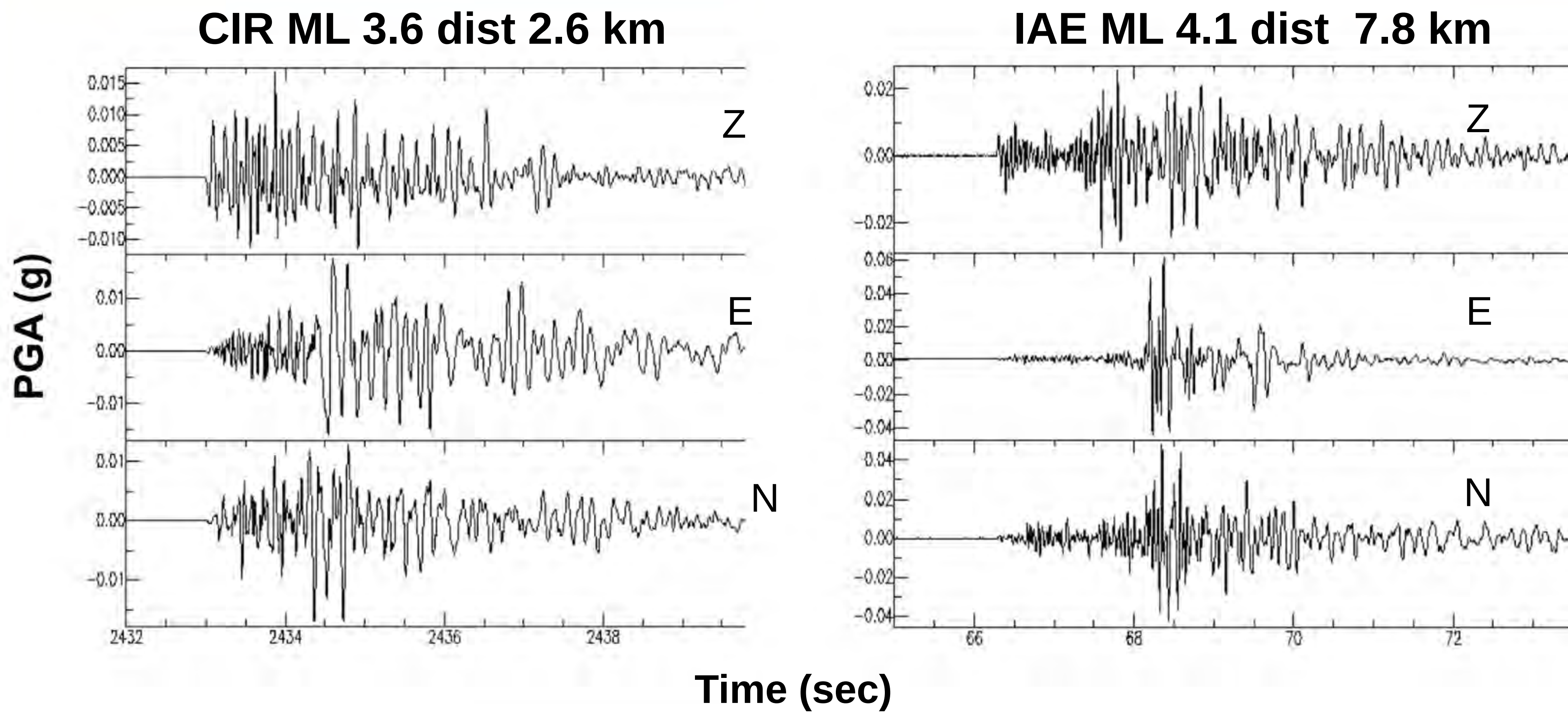
Dataset

- ML ≥ 3.0 2000 – 2011
- Require an observations ≤ 200km
- 164 Earthquakes ML 3.0 to ML 5.9

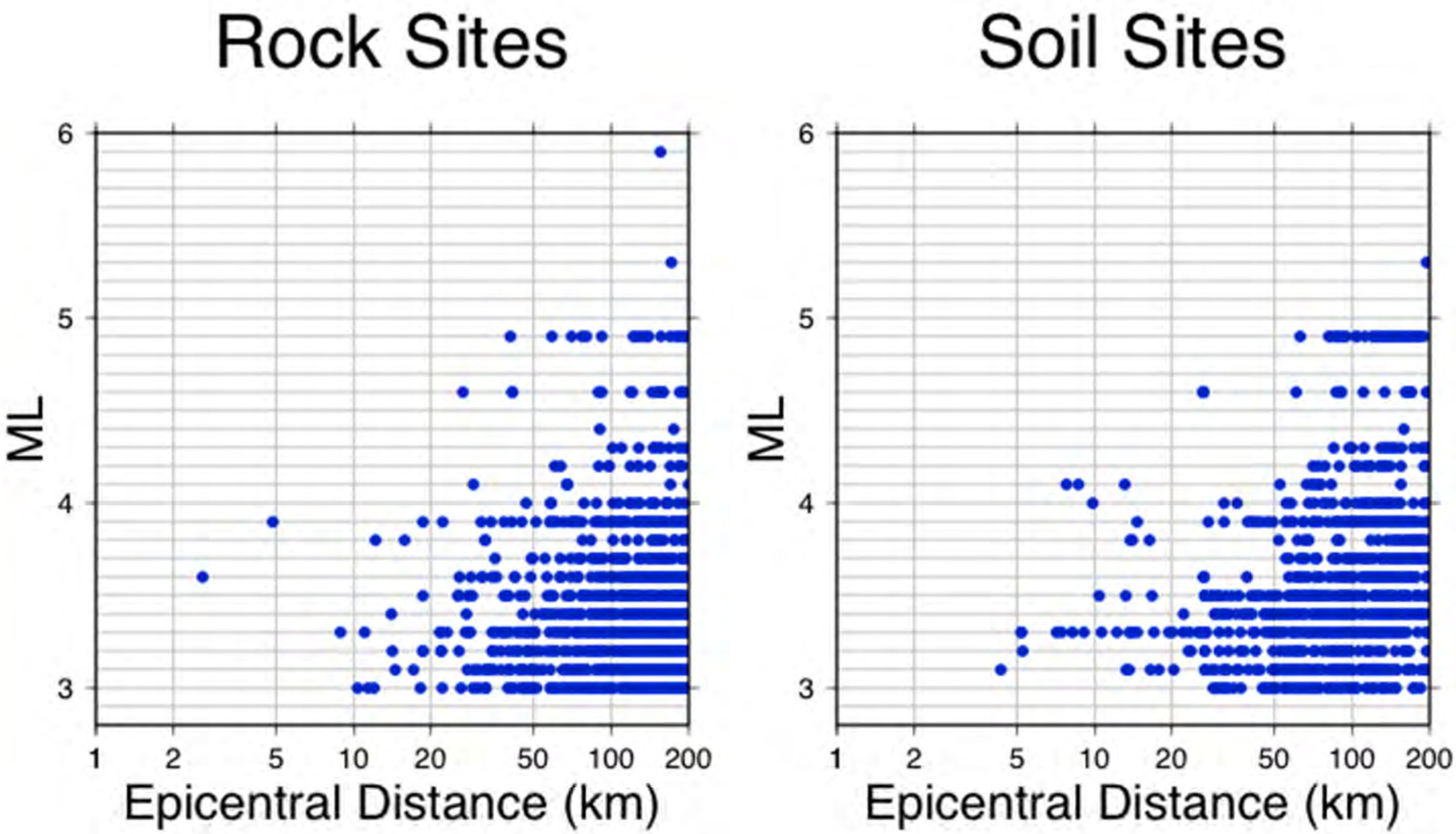
Data Processing

- Used SAC transfer command to:
  - Remove instrument response
  - Convert to acceleration and velocity
- Visually inspected all waveforms:
  - 5 min time window dominated by event not other high-frequency spikes
  - No gaps
  - SNR ~> 2
  - No visible trend

Example Waveforms



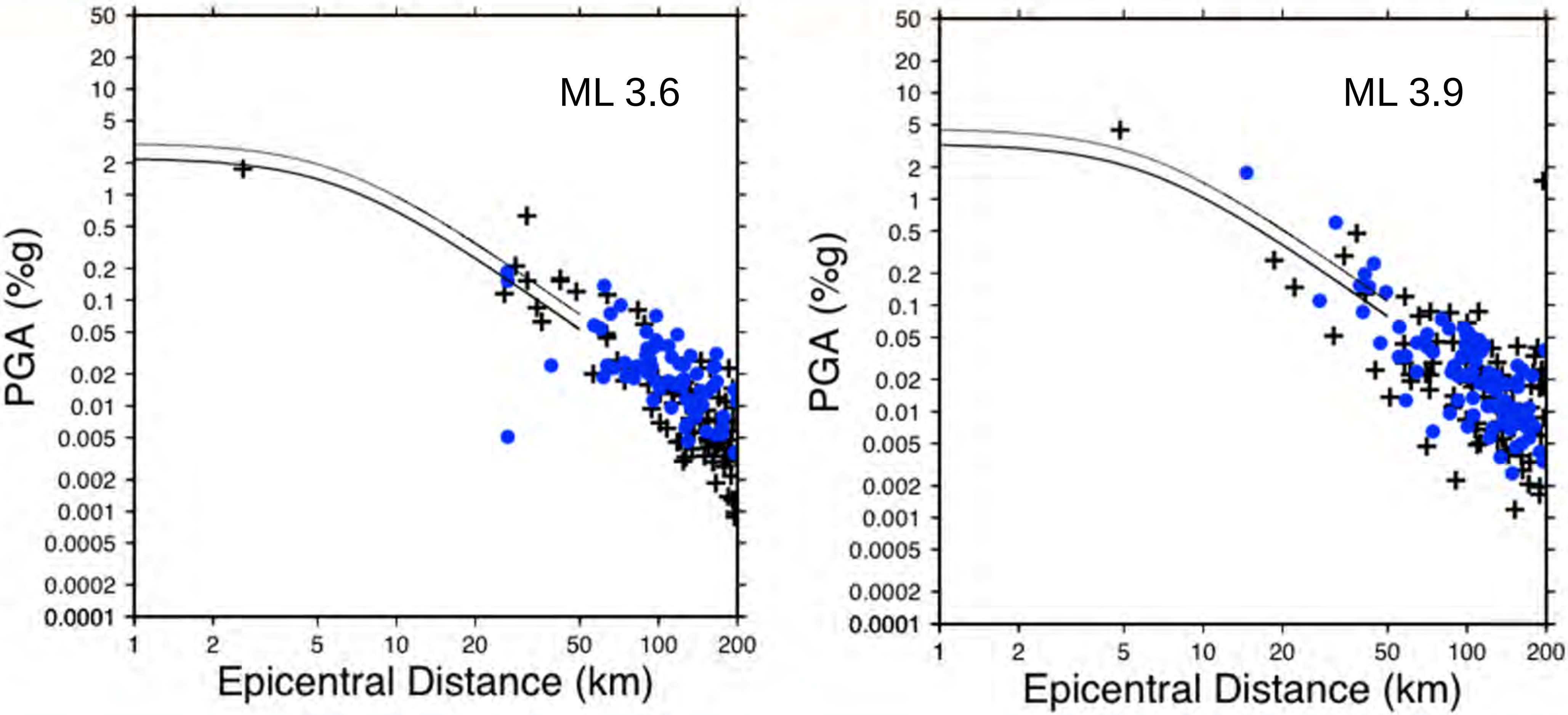
Magnitude-Distance Distribution



Issues with Data

- UVW
- Station Response Files

PGA Compared to ShakeMap Small



Issues Comparing to Equations

- Magnitude Mw vs ML
- Distance Term
  - Small earthquakes don’t calculate rupture plane
  - Hyocenter very uncertain
- Peak Ground Motion vs. Orientation-independent ground motion (GMRotI50) (Boore et al. 2006)

Minimum requirements for modeling

-Geologic representation of fault model

- Roten et al. fault model (default)

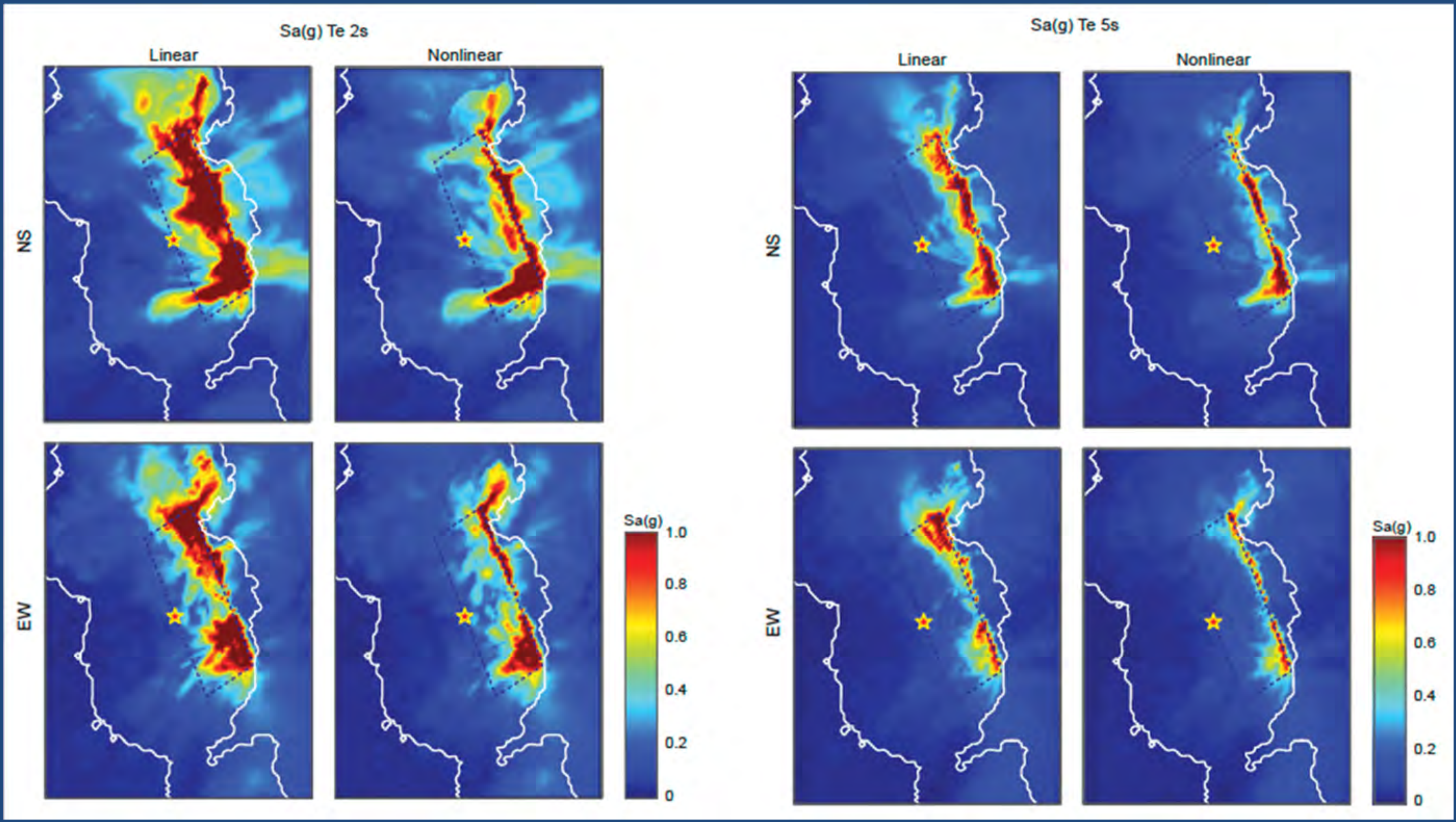
-Qiming sensitivity study ??

-Urban hazard maps in 2 years based on simulations and NGA relations

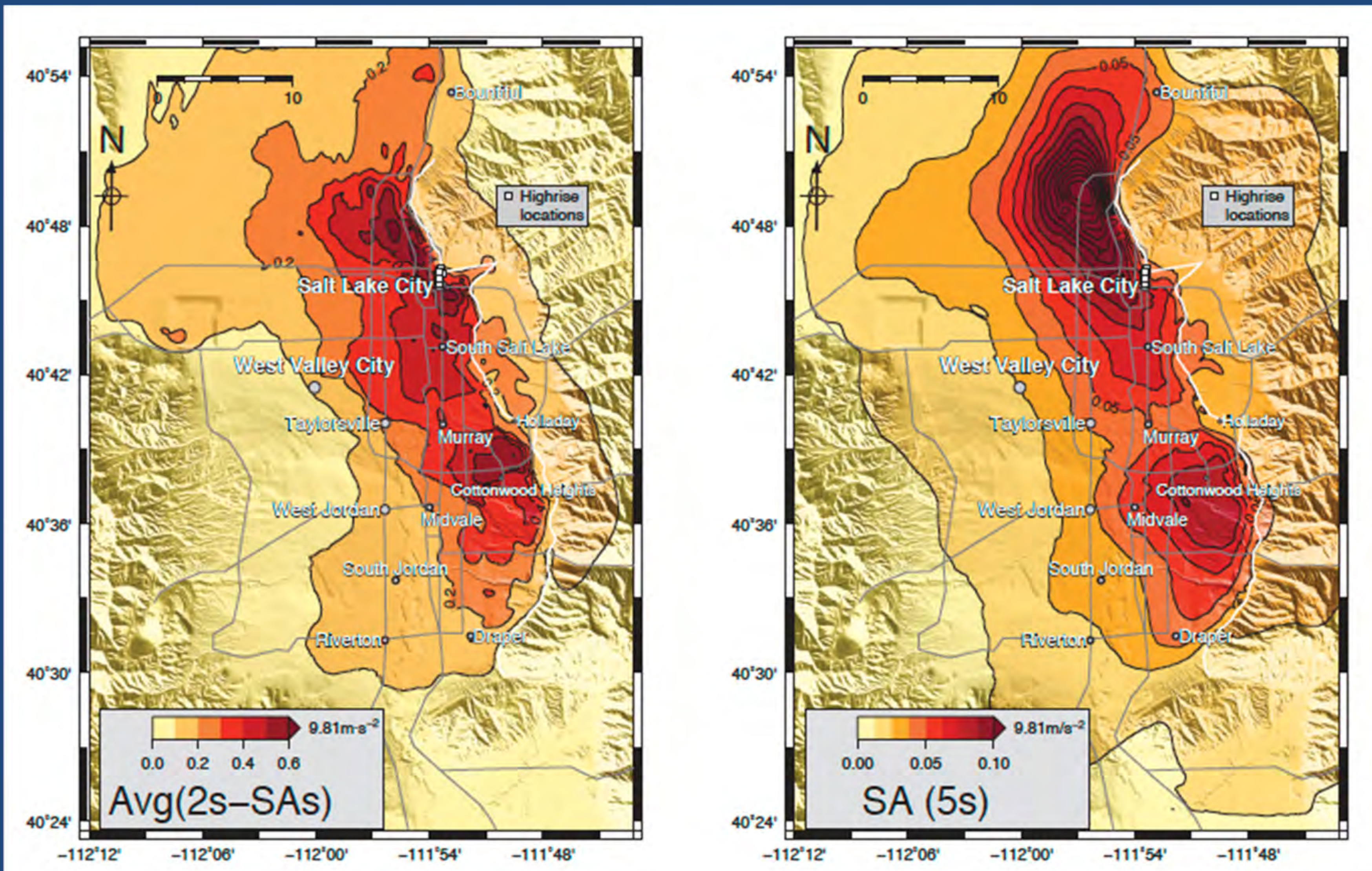
-Understanding rapid decay of ground motions with distance (wrt NGA models)

-Check CVM and publish

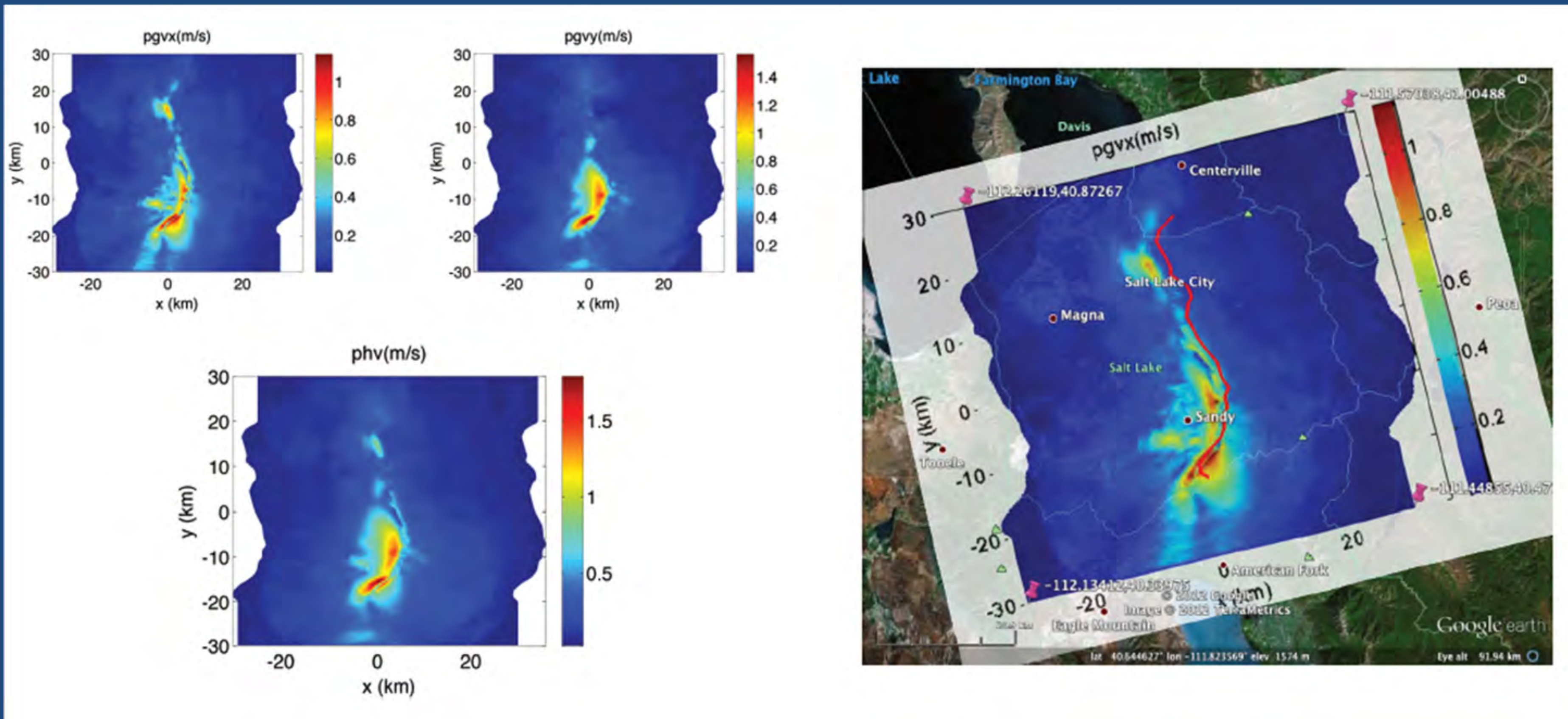
CMU results: 2 and 5 s, linear/non-linear



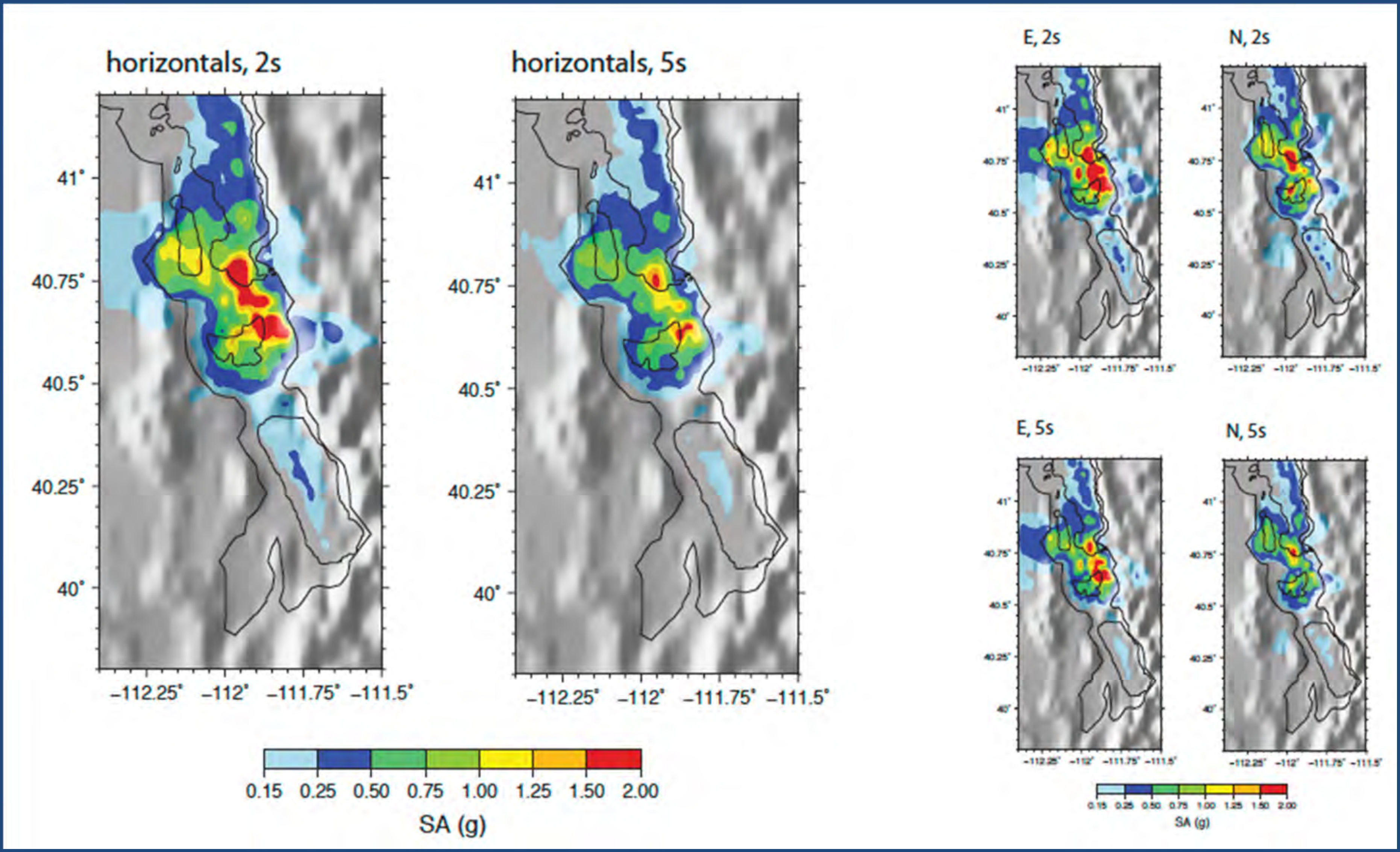
SDSU/UU results: 2 and 5 s SA

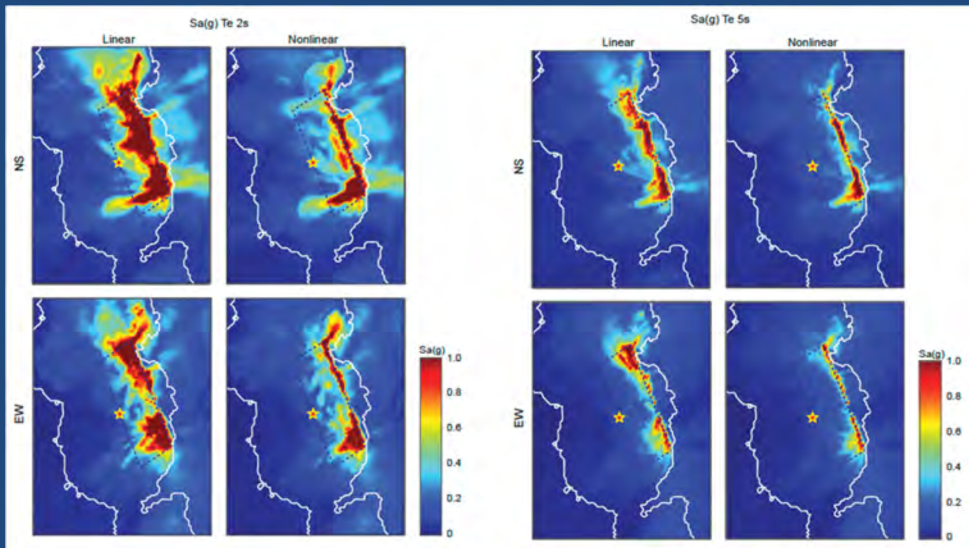


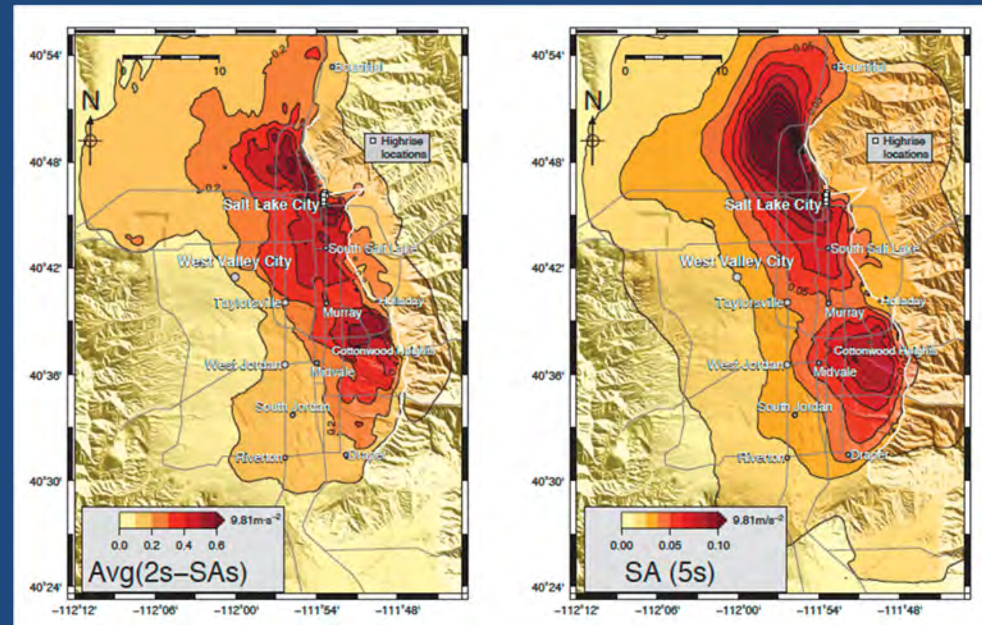
UCSD results: PGVXY, PHV

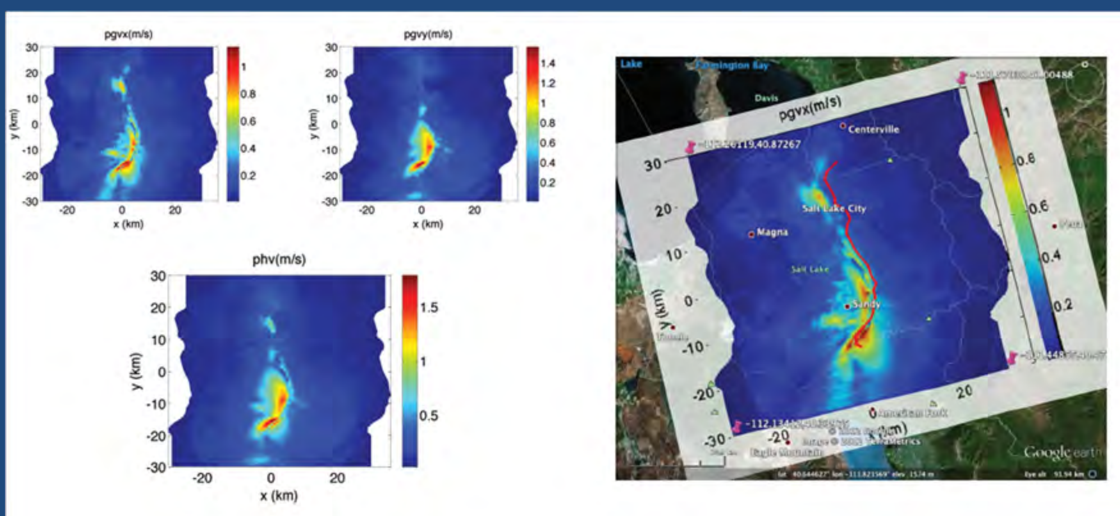


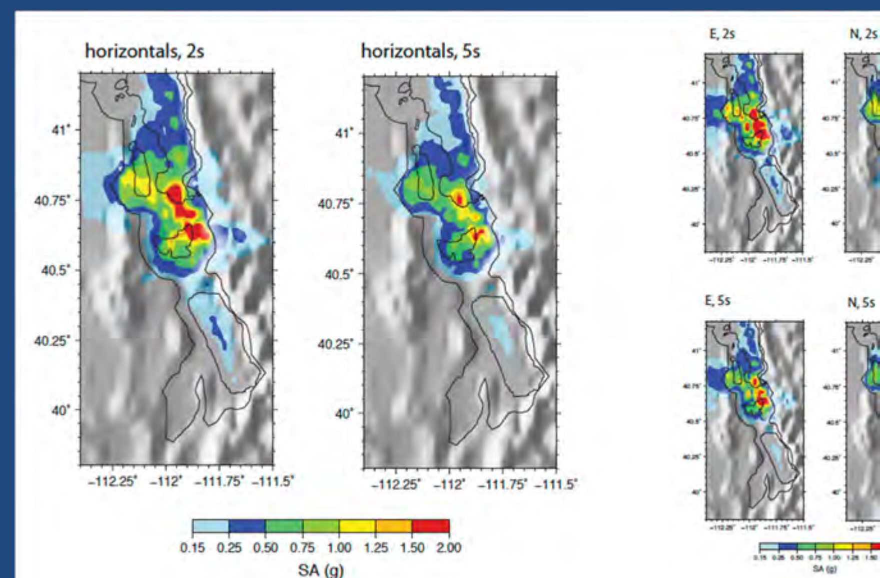
USGS results: 2 and 5 s SA




Sa(g) Te 2s
Linear
Nonlinear
NS
EW
Sa(g)
Sa(g) Te 5s
Linear
Nonlinear
NS
EW
Sa(g)


N
Highrise locations
Bountiful
Salt Lake City
West Valley City
South Salt Lake
Taylorsville
Murray
Holladay
Cottonwood Heights
West Jordan
Midvale
South Jordan
Riverton
Draper
9.81m·s⁻²
Avg(2s–SAs)
SA (5s)


pgvx(m/s)
pgvy(m/s)
phv(m/s)
y (km)
x (km)
pgvx(m/s)
Centerville
Salt Lake City
Magna
Sandy
American Fork
Google earth


horizontals, 2s
horizontals, 5s
E, 2s
N, 2s
E, 5s
N, 5s
SA (g)