Simulation and Validation of Long-Period Earthquake Ground Motion in the Kanto Basin in Japan

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Objective

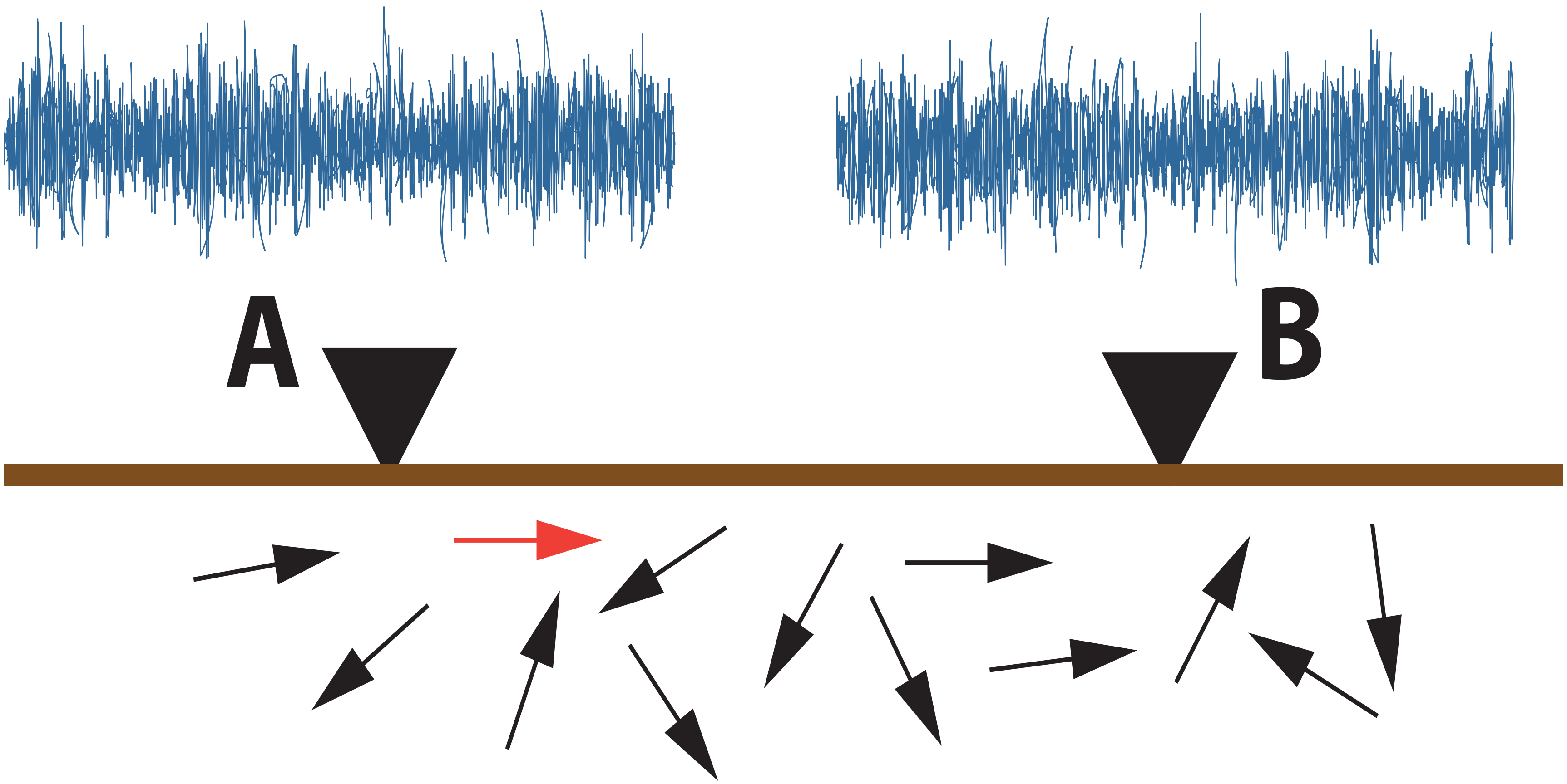
- Part of SCEC's VISES project with ERI and DPRI
- Verification and validation of earthquakes in Japan since 2000 (dense coverage)
- Beroza et al: Impulse response from ambient seismic field
- Use Hercules for simulating long-period earthquakes
- First use point sources and then extended faults
- Part of High-F project: To achieve realistic simulations from 0 to 10 Hz

Basic question

- How do seismic waves propagate from the rupture to produce strong shaking at the Earth's surface?

- Study the basin amplification effects in the Kanto region

Ambient Seismic Field



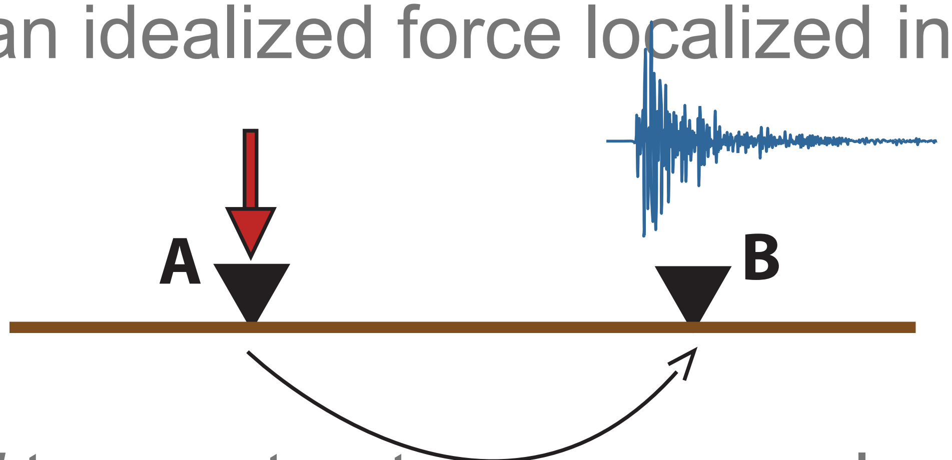
New view of this "noise" as a useful signal

Courtesy of Greg Beroza

Green’s Function

Used to solve linear differential equations subject to specific initial conditions and/or boundary conditions.

For the wave equation, the Green’s function is the response to an idealized force localized in space and time.



Fundamental to construct more general solutions to the wave equation to study Earth structure and seismic sources.

Courtesy of Greg Beroza

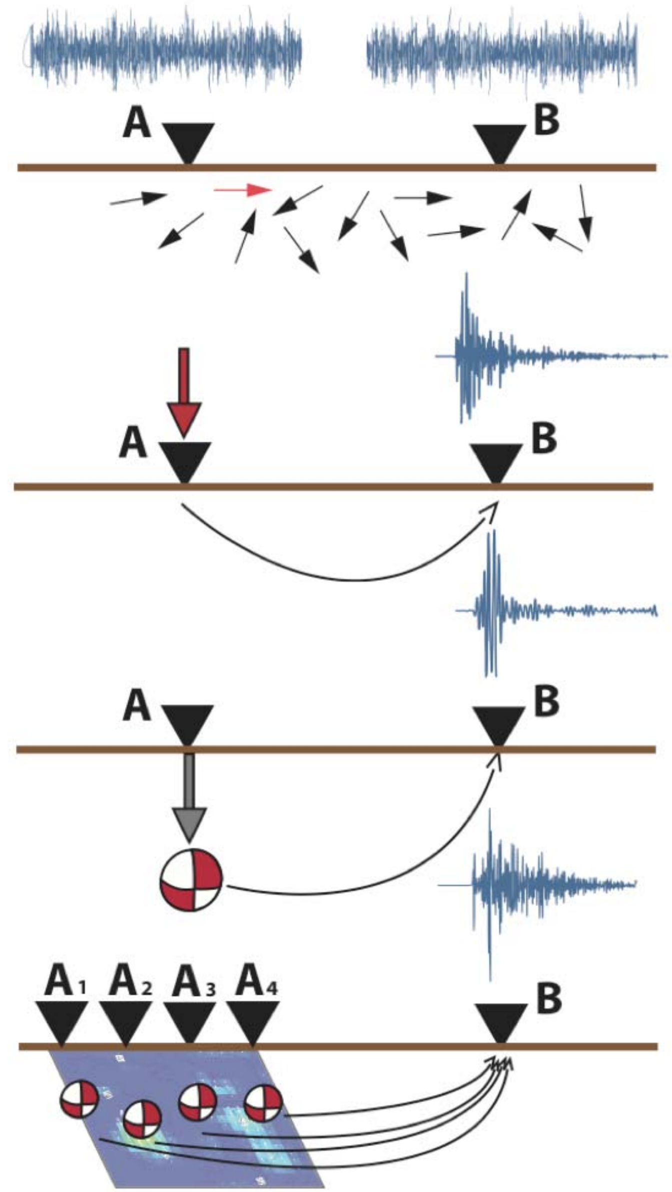
The Virtual Earthquake Approach

(1) Record weakly coherent background.

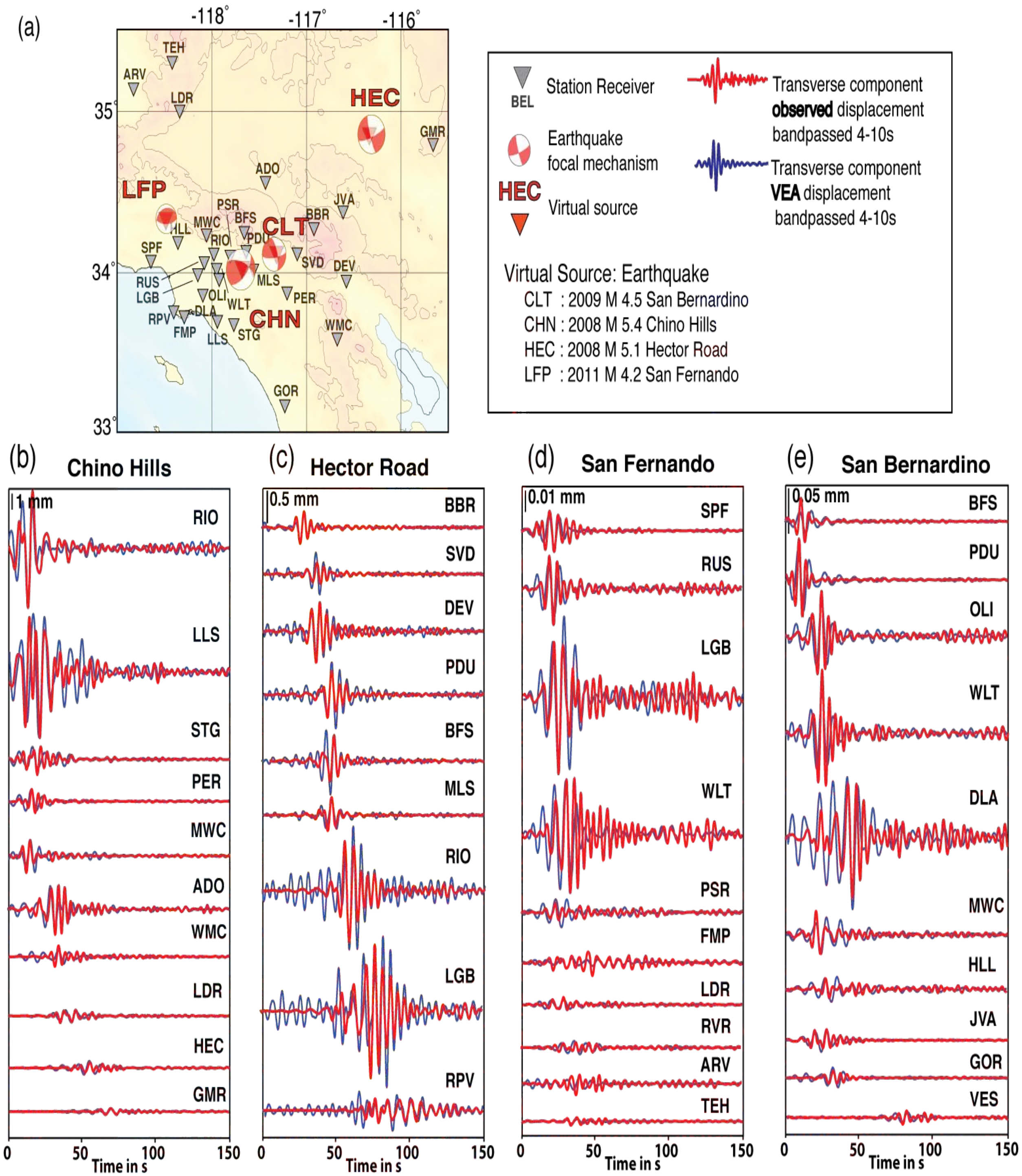
(2) Extract surface impulse response.

(3) Correct for depth & mechanism.

(4) Large Magnitude via superposition.



Courtesy of Greg Beroza



Virtual Earthquake Approach validated by 4 moderate earthquakes.

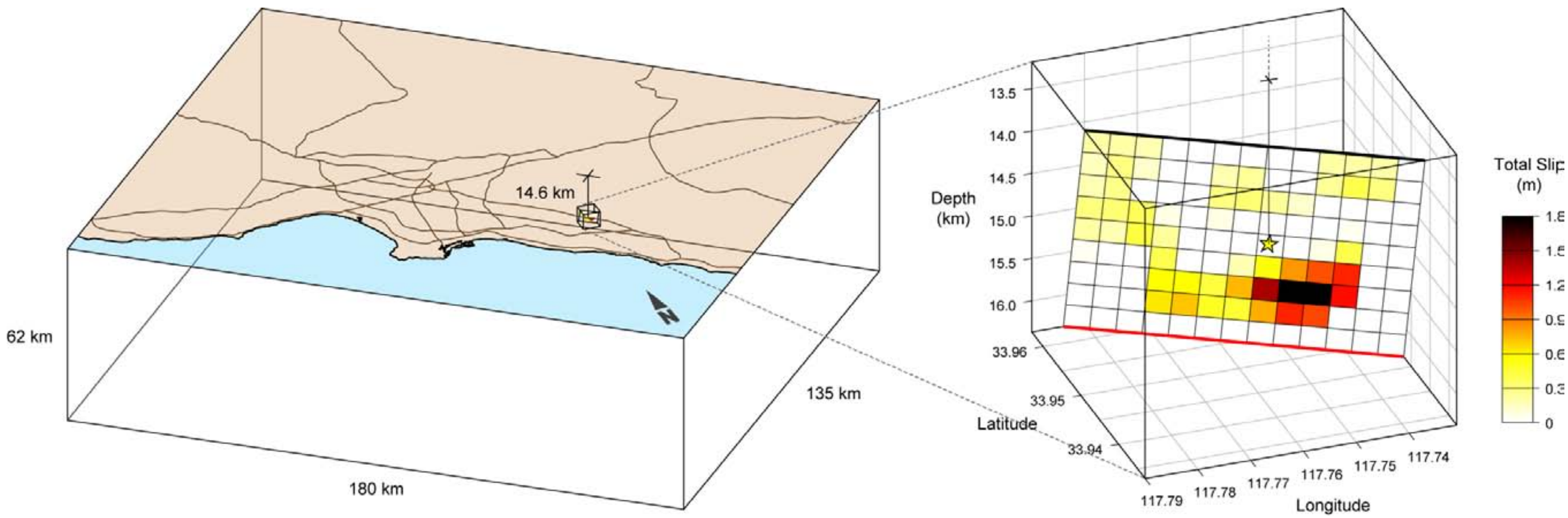
Basin amplification is apparent.

It works.

Courtesy of
Greg Beroza

Denolle et al. (2012)

2008 M5.4 Chino Hills Earthquake with Region of Interest Validation



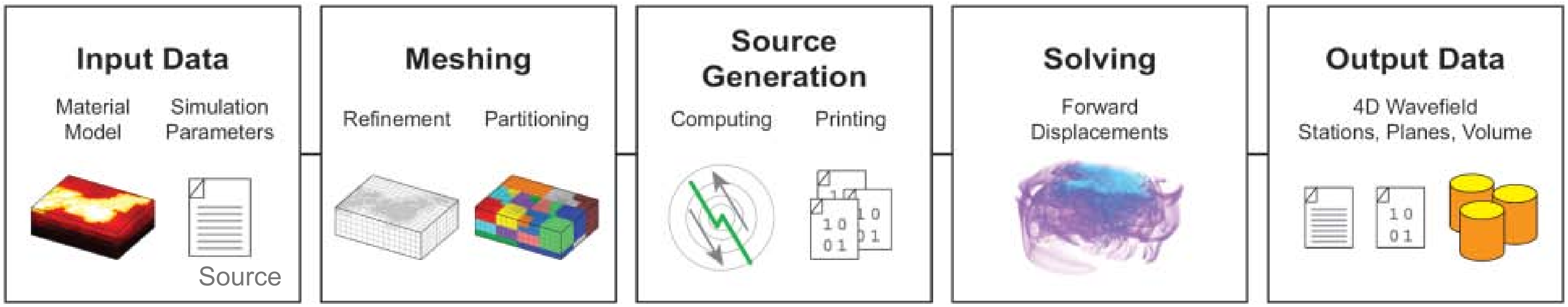
Simulation Domain:	180 x 135 x 62 km^3
Material Model:	CVM-S v4.1
Minimum Vs:	200 m/s
Maximum Frequency:	4 Hz
Software:	Hercules
Processors:	24,000
Time:	31 hrs

Source model

» Shao et al. (2012)
J. Geophys. Res. 117:B07307

Hercules

Our octree-based finite element tool for modeling earthquake ground motion* (Tu et al., SC2006)



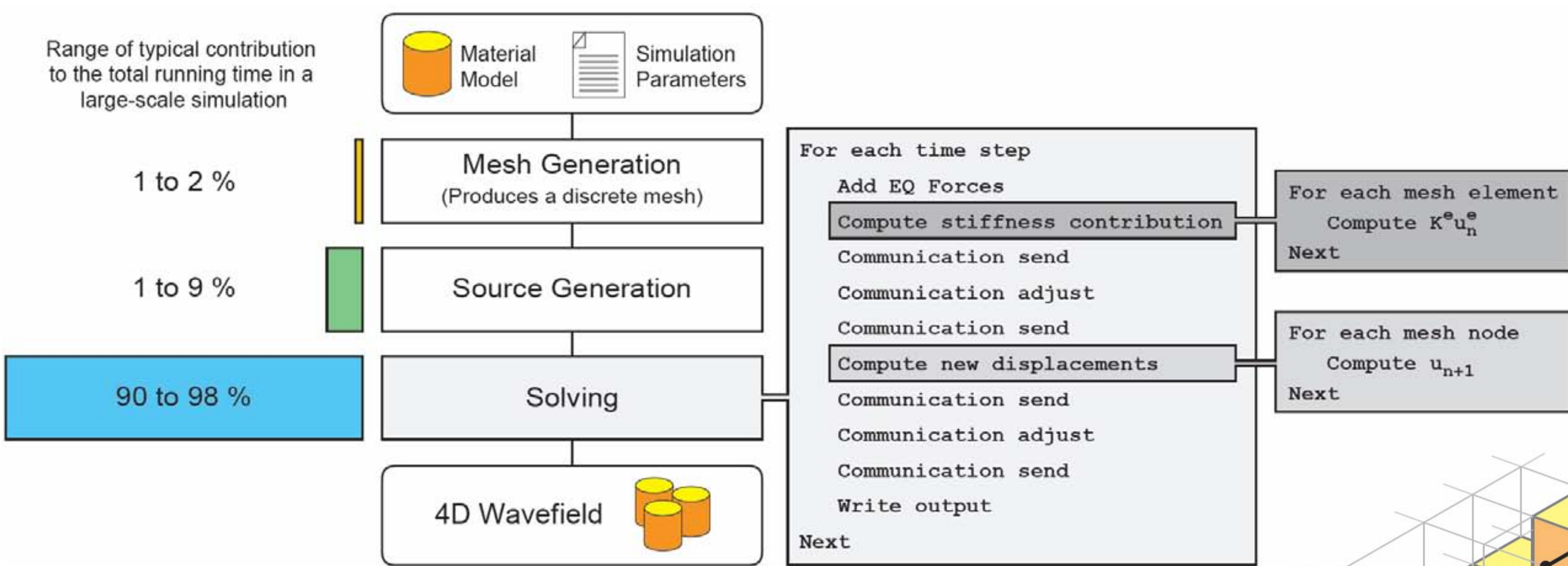
Hercules has been used for verification and validation studies (Bielak et al, GJI 2010; Taborda et al, CiSE 2011)

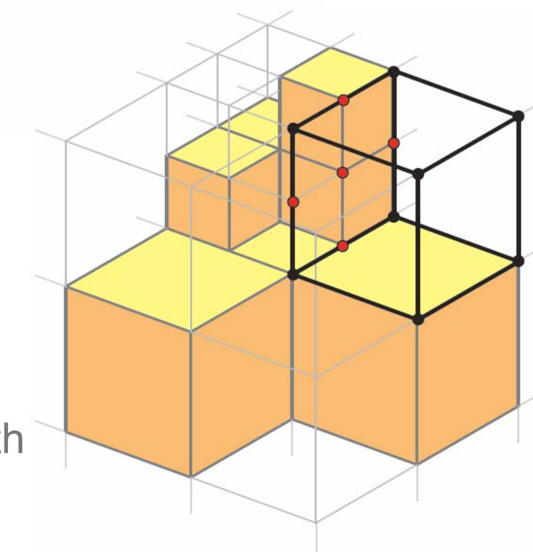
- **TeraShake (2005–2007) SCEC**
- **ShakeOut (2007–2009) SCEC+USGS**
- **Chino Hills (2008–2011) SCEC**
- **Volvi (2008–2010) Euroseis E2VP**

* and simplified building models

Hercules

Simulation Stages **Solving Algorithm**

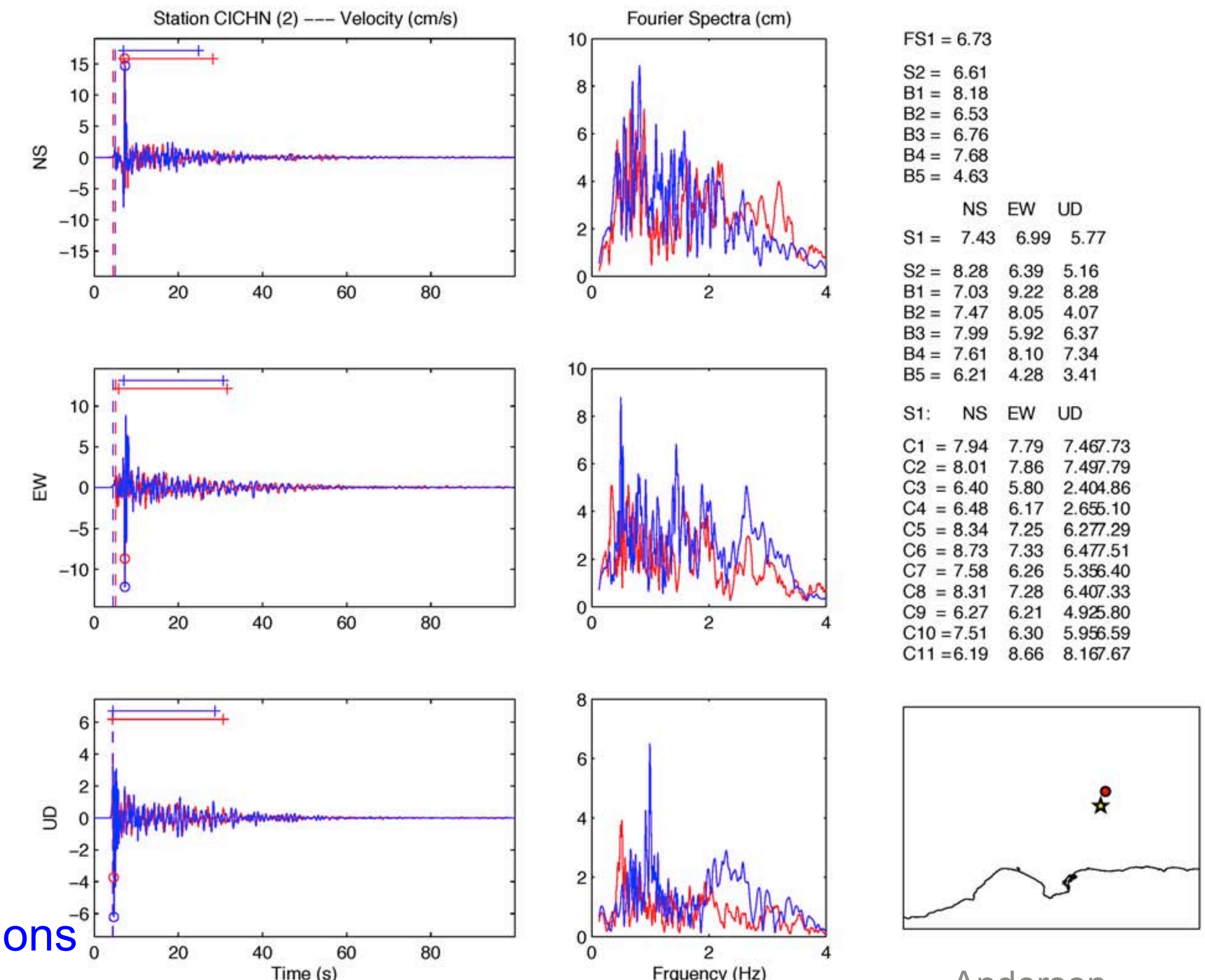




Octree-based FEM mesh

tailored to shear wave length

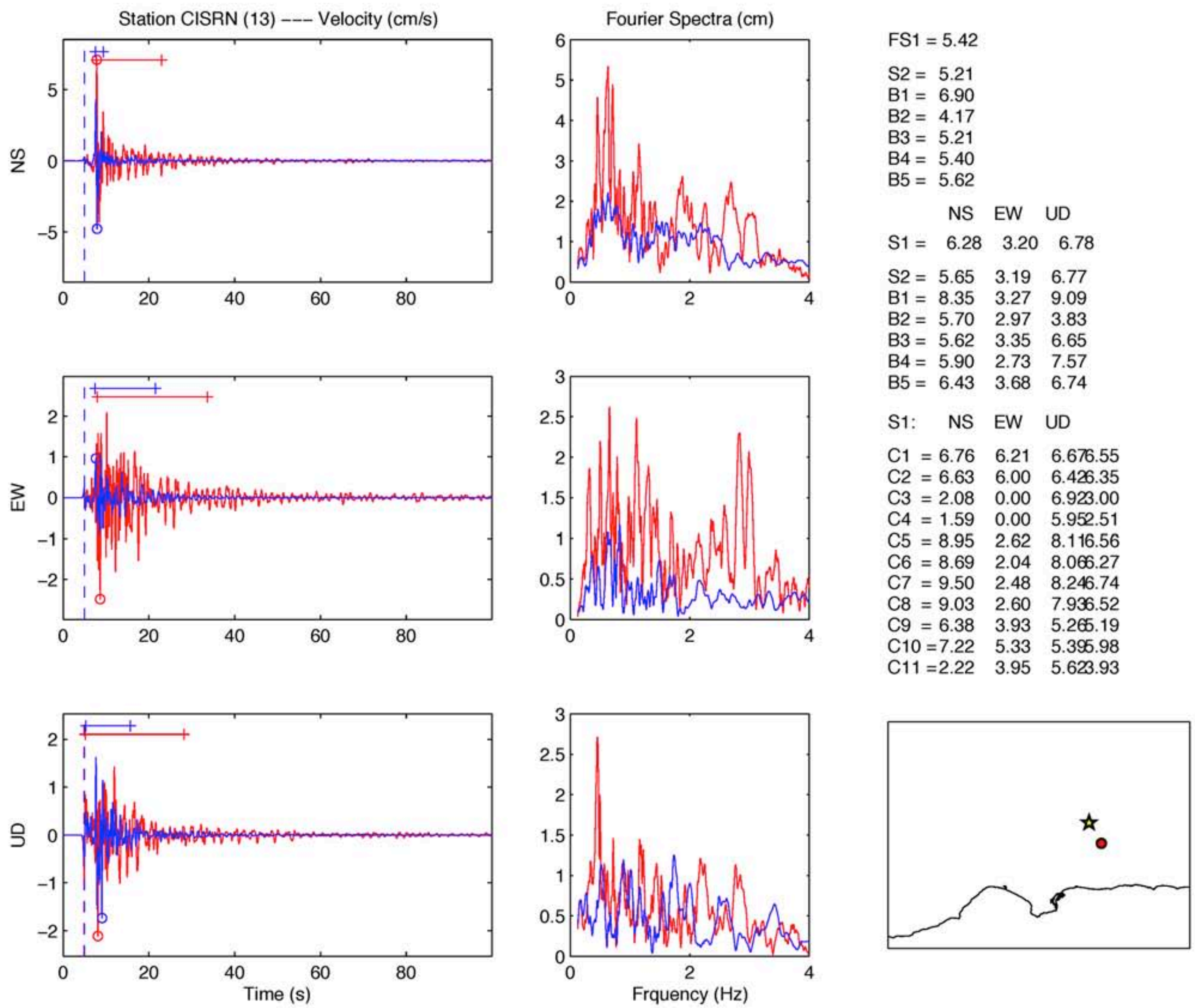
Observations vs synthetics



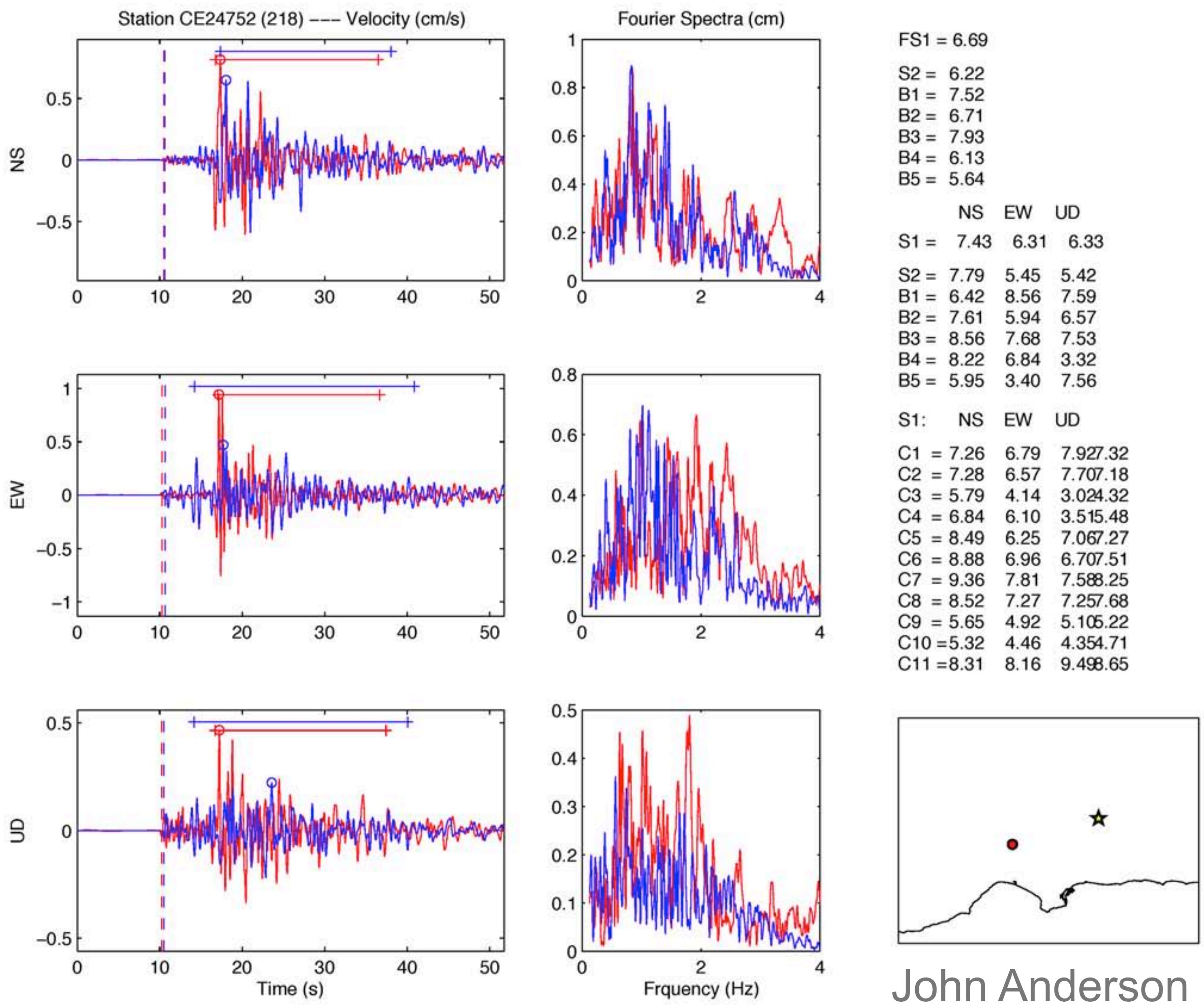
Red – data
Blue - simulations

Anderson, 2004

Observations vs synthetics

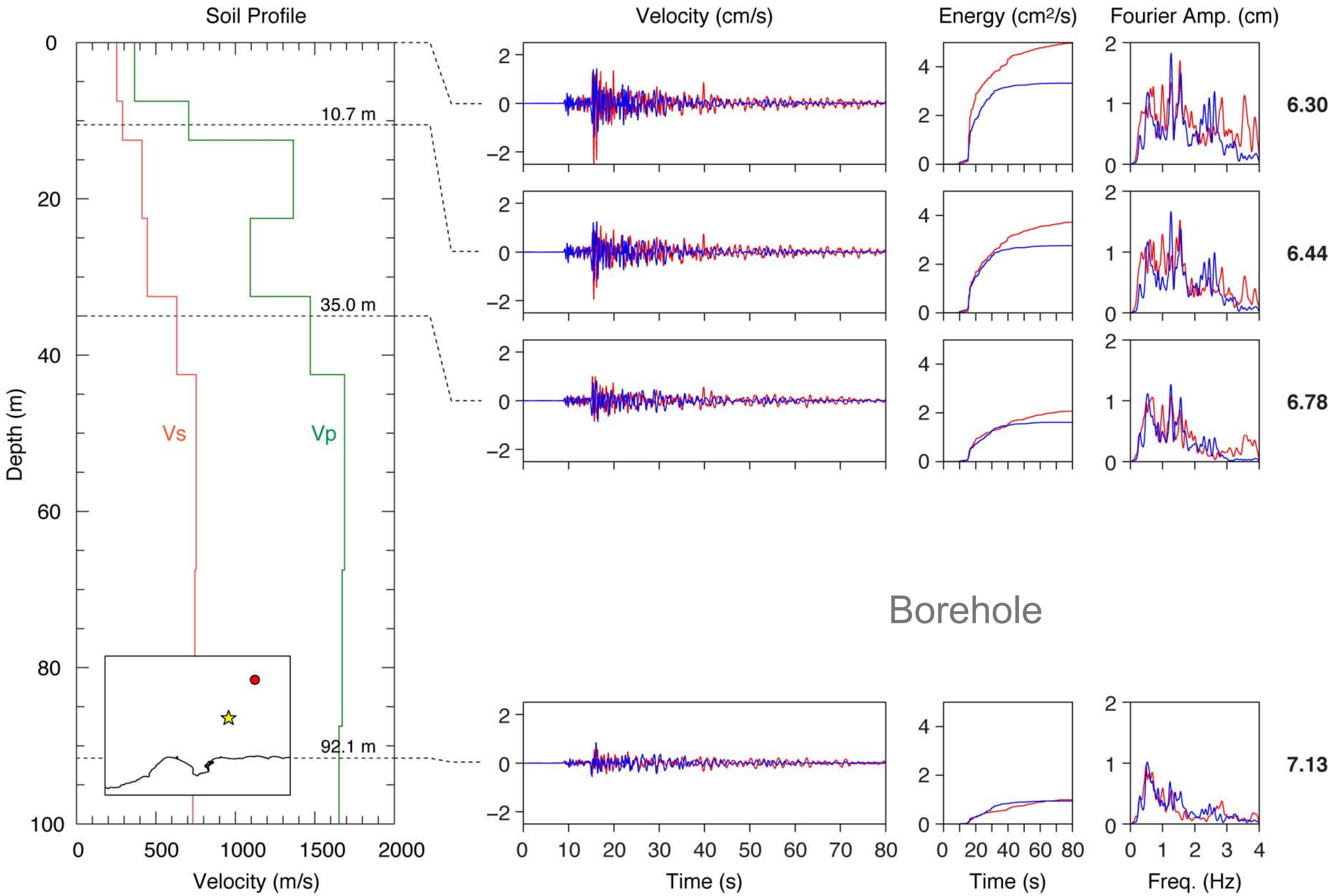


Observations vs synthetics

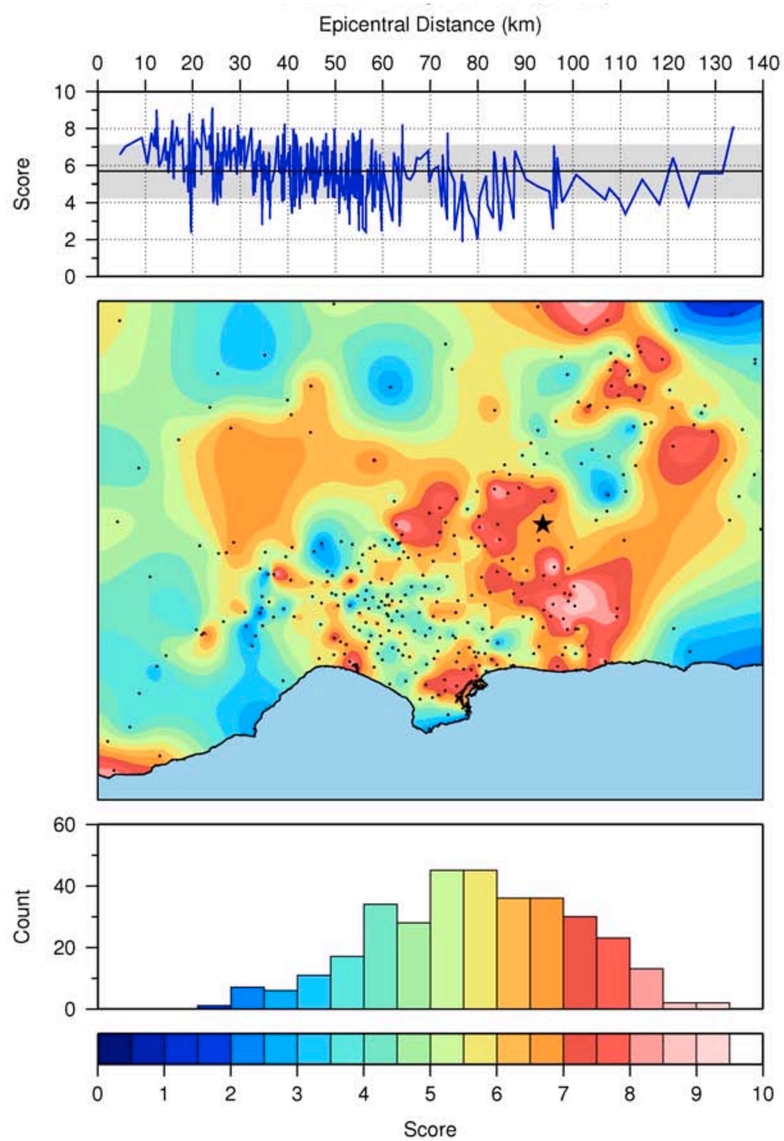


John Anderson (2009)
GOF criteria

Geotechnical layers

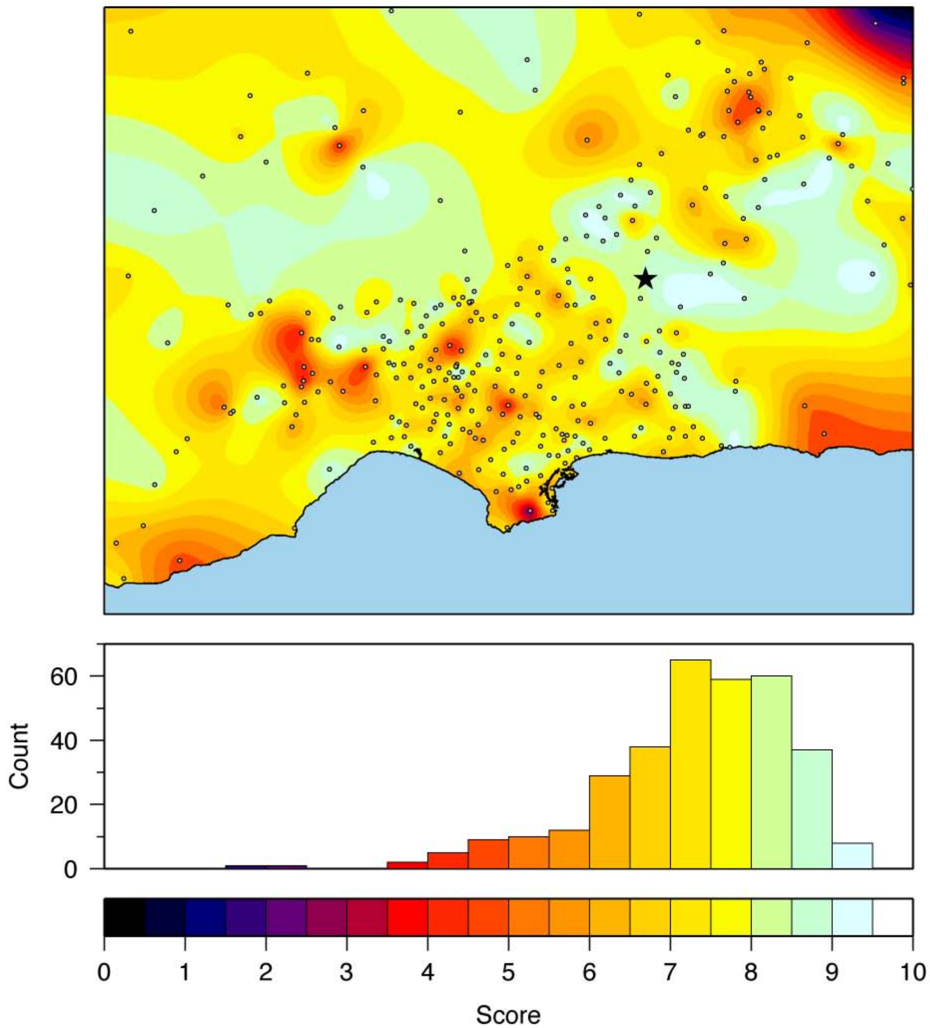


Global score for PGV



Goodness-of-fit PGV

0.1 – 0.25 Hz



MATERIAL MODEL --- ELEVATION DATA

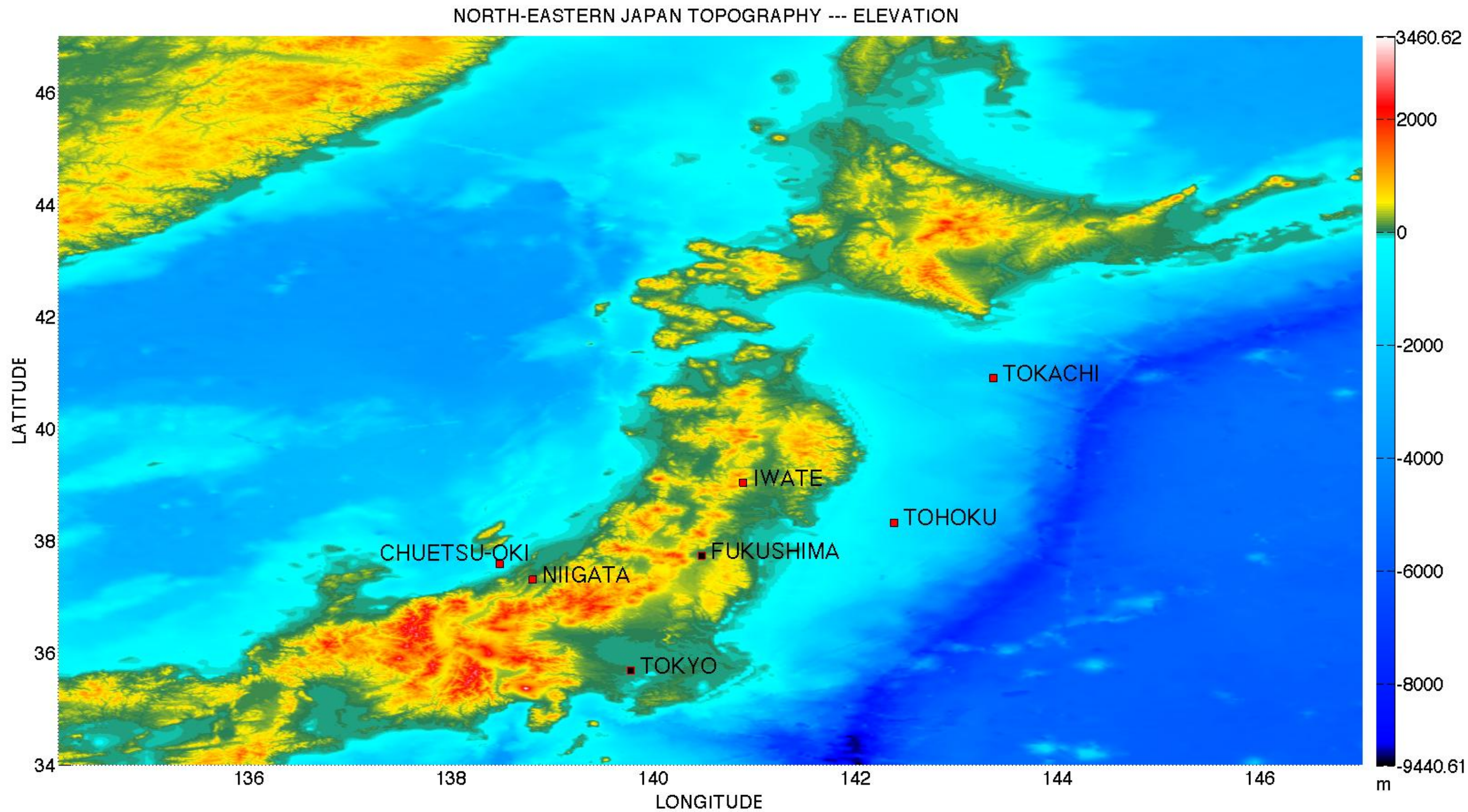


Table 2. Earthquakes since 2000 selected for simulation validation

YEAR	REGION	EQ NAME	# RECORDS < 200 km
2003	USA	San Simeon	21
2004	USA	Parkfield	78
2010	USA	El Mayor-Cucapah	134
2000	JAPAN	Tottori	171
2004	JAPAN	Niigata	246
2007	JAPAN	Chuetsu-Oki	286
2008	JAPAN	Iwate	186

Epicenter of Tottori earthquake is out of the available material model

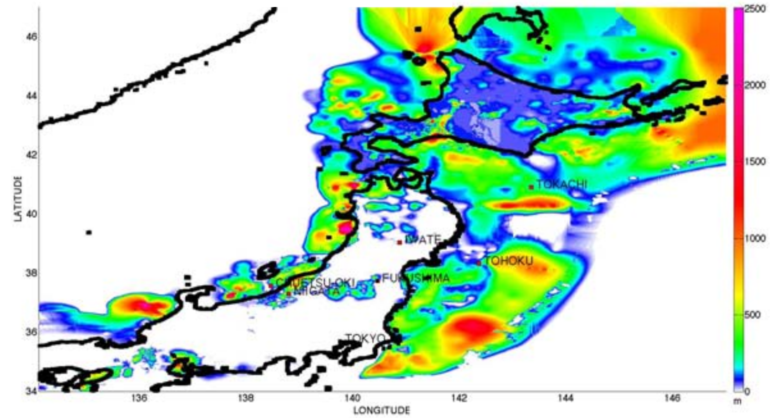
Velocity model, NIED; Ichimura

Table is taken from Virtual Institute for the Study of Earthquake Systems (VISES) Proposal

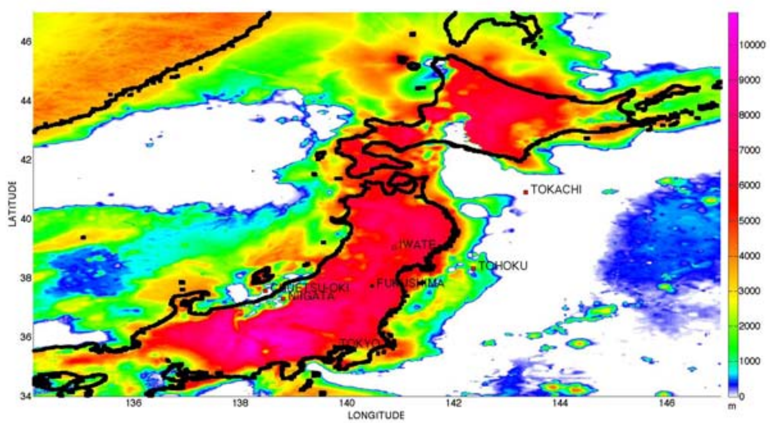
MATERIAL MODEL --- LAYER PROPERTIES

Layer	Vp(km/s)	Vs(km/s)	ρ (g/cm^3)	Qp	Qs
1	1.7	0.35	1.80	119	70
2	1.8	0.5	1.95	170	100
3	2.0	0.6	2.00	204	120
4	2.1	0.7	2.05	238	140
5	2.2	0.8	2.07	272	160
6	2.3	0.9	2.10	306	180
7	2.4	1.0	2.15	340	200
8	2.7	1.3	2.20	442	260
9	3.0	1.5	2.25	510	300
10	3.2	1.7	2.30	578	340
11	3.5	2.0	2.35	680	400
12	4.2	2.4	2.45	680	400
13	5.0	2.9	2.60	680	400
14	5.5	3.2	2.65	680	400
15	5.8	3.4	2.70	680	400
16	6.4	3.8	2.80	680	400
17	7.5	4.5	3.20	850	500
18	5.0	2.9	2.40	340	200
19	6.8	4.0	2.90	510	300
20	8.0	4.7	3.20	850	500
21	5.4	2.8	2.60	340	200
22	6.5	3.5	2.80	510	300
23	8.1	4.6	3.40	850	500

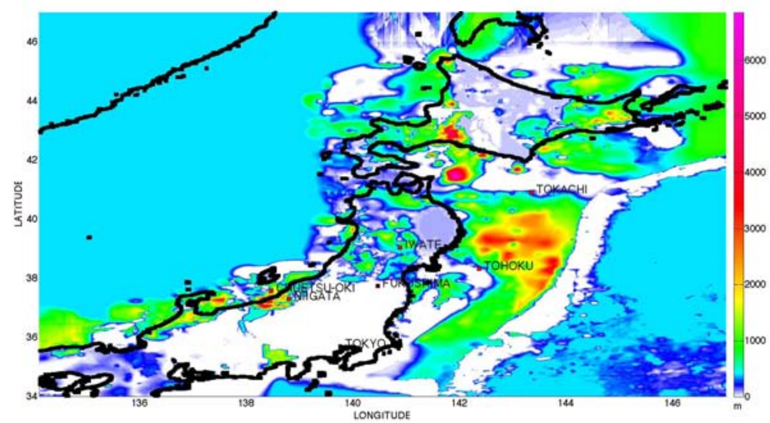
LAYER 3



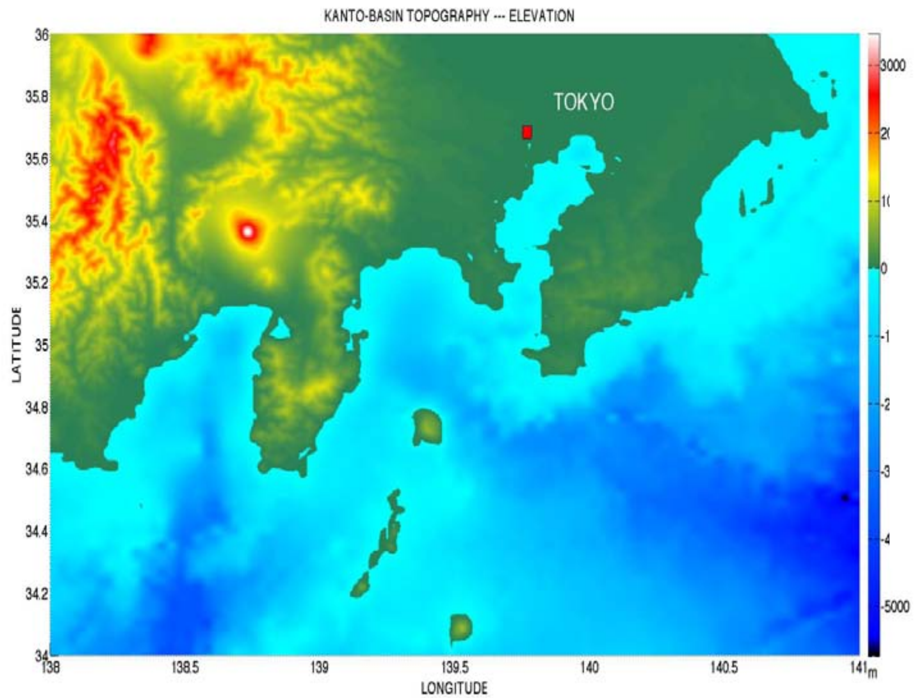
LAYER 14



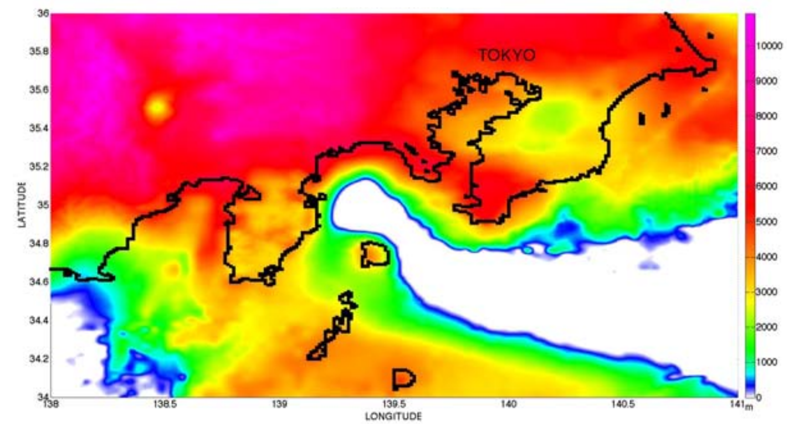
LAYER 11



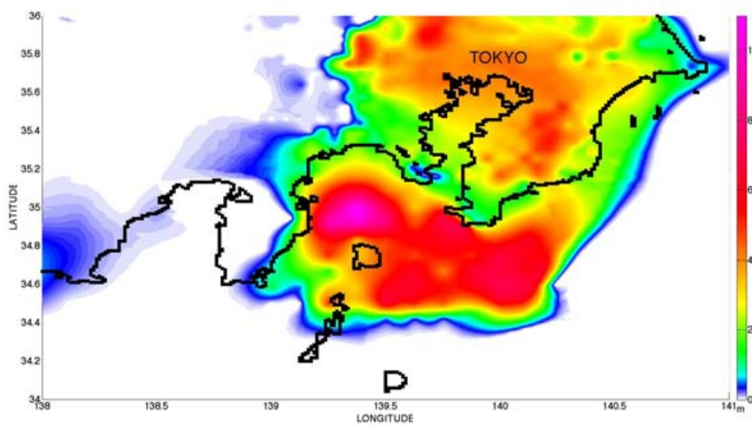
MATERIAL MODEL (KANTO-BASIN)



LAYER 14



LAYER 2



LAYER 9