3D Simulation of ground motion including topography

A collaboration with QuakeCoRE to deploy Hercules on NeSI HPC platforms

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Hercules

A parallel finite element code for earthquake ground motion simulation



» Tu et al. (2006), SC'06 Paper

- » Taborda et al. (2010), PDL CMU Tech. Report
- » Bielak, Karaoglu and Taborda (2011), Geophysics 76(6):T131-T145
- » Restrepo, D. and Bielak, J. (2014). Int. J. Numer. Meth. Eng. 100(7): 504–533



Virtual Topography

A method to include the effects surface irregularities



» Restrepo, D. and Bielak, J. (2014). Int. J. Numer. Methods Eng., accepted for publication.

Simulations for southern California including topography



Simulation domain of 65 km x 45 km x 45 km, focus on the vicinity of the Ventura basin and the Oxnard plain. Work doe with the support of the SCEC-core program during 2016 (Bielak, Restrepo, Taborda; Project #16-093)

Simulations for southern California including topography



Event	year	longitude	latitude	Depth	Mw	Event name
1	2009	-118.90307	34.06972	15.5	4.42	Westlake Village
2	2007	-118.64873	34.28639	7	4.66	Chatsworth
3	2003	-118.75817	34.26759	8.5	3.59	Simi Valley



Velocities (Vel), Fourier spectra (FFT) and transfer function, H=FFT(VT)/FFT(Flat), for Station 41 (see top-left). Comparison for the Flat (blue lines) and the VT models (red lines). Top: Event 1, Mw = 4.42. Bottom: Event 2, Mw = 4.66.

Simulations for southern California including topography



20

500

30

1000

40x-coordinate, km 50

1500

60

m.a.s.l

2000

Metrics comparison for event 2, Mw = 4.42 (left, diagonal 2) and event 1, Mw = 4.66 (right, diagonal 4). (a) Topographic profile and variation of the CVM-S model along the diagonals, (b) square root of the energy, (c) peak ground velocity, (d) peak ground acceleration, and (e) Housner intensity.

Simulations for southern California including topography



Ratio comparison for event 2, Mw = 4.42 (left, diagonal 2) and event 1, Mw = 4.66 (right, diagonal 4), Topography / Flat model. (a) Topographic profile and variation of the CVM-S model along the diagonals, (f) square root of the energy,

(g) peak ground velocity, (h) Housner intensity, and (i) peak ground acceleration.

Plans for Collaboration with QuakeCoRE

Simulations for New Zealand including topography

- » Deploy Hercules on Fitzroy
- » Choose intended model:
 - Option 1, small model for Christchurch (aftershock?)
 - Option 2, large model for Christchurch (main event?)
 - Option 3, larger model for South Island (scenario/historical?)
- » Verification with QuakeCoRE efforts
- » Analysis of effects of topography on validation
- » Impact on scenario earthquake









Highlighted in blue are main goals for this year (towards the annual meeting)

Topographic amplification of ground motions at Port Hills, Christchurch, during the Canterbury earthquakes

Seokho Jeong and Brendon Bradley QuakeCoRE/University of Canterbury

Motivations

Legend

Red Zones

Localized damage pattern in the residential area of of Port Hills





Spatial variability of building damage following the Mw 6.2 February 2011 earthquake (Damage map provided by Nick Horspool, GNS Science). Damage ratios are based on EQC data derived from visual street surveys conducted following the quake. Dashed black line indicates the edge of the Port Hills to the south and the Canterbury Plains to the north as defined by the surface topography. Location of array seismometers analysed in this study and GeoNet strong motion stations are shown as triangles. The epicentre and projection of the upper edge of the fault plane (Beavan et al., 2011) are indicated by the grey star and dashed line respectively.

5 km

Google Earth

mage © 2016 CNES / Astrum mage © 2016 DigitalGlobe nage © 2016 TerraMetrics

Planned research activities

Field monitoring, simulations, and verification/validation

- » Field monitoring (Recording earthquake ground motions and the ambient vibrations)
- » 3D regional scale ground motion simulation accounting for the topography (SPECFEM3D)
- » Qualitative validation with damage map (red zones, building damage, and mass movements)
- » Verification with Hercules (collaboration with Ricardo and Khurram from the University of Memphis)
- » Local scale site response simulation
- » Quantitative validation with recorded ground motions
- » Benchmark our effort against existing studies

Field instrumentation

Earthquake ground motions and ambient vibrations



3D Regional scale simulation

- » 3D regional scale ground motion simulation accounting for the topography (SPECFEM3D)
- » Simulations on NeSI PAN or Fitzroy
- » Model domain 75km x 65km x 30km
- » dx=125m ~ 375m; fmax > 3Hz (Topographic effects are expected at f=1~3Hz)
- » Canterbury velocity model to be implemented soon
- » Artificial sources and recorded events

