Regional Scale Building Response from Broadband (0-5 Hz) Ground Motion Simulations

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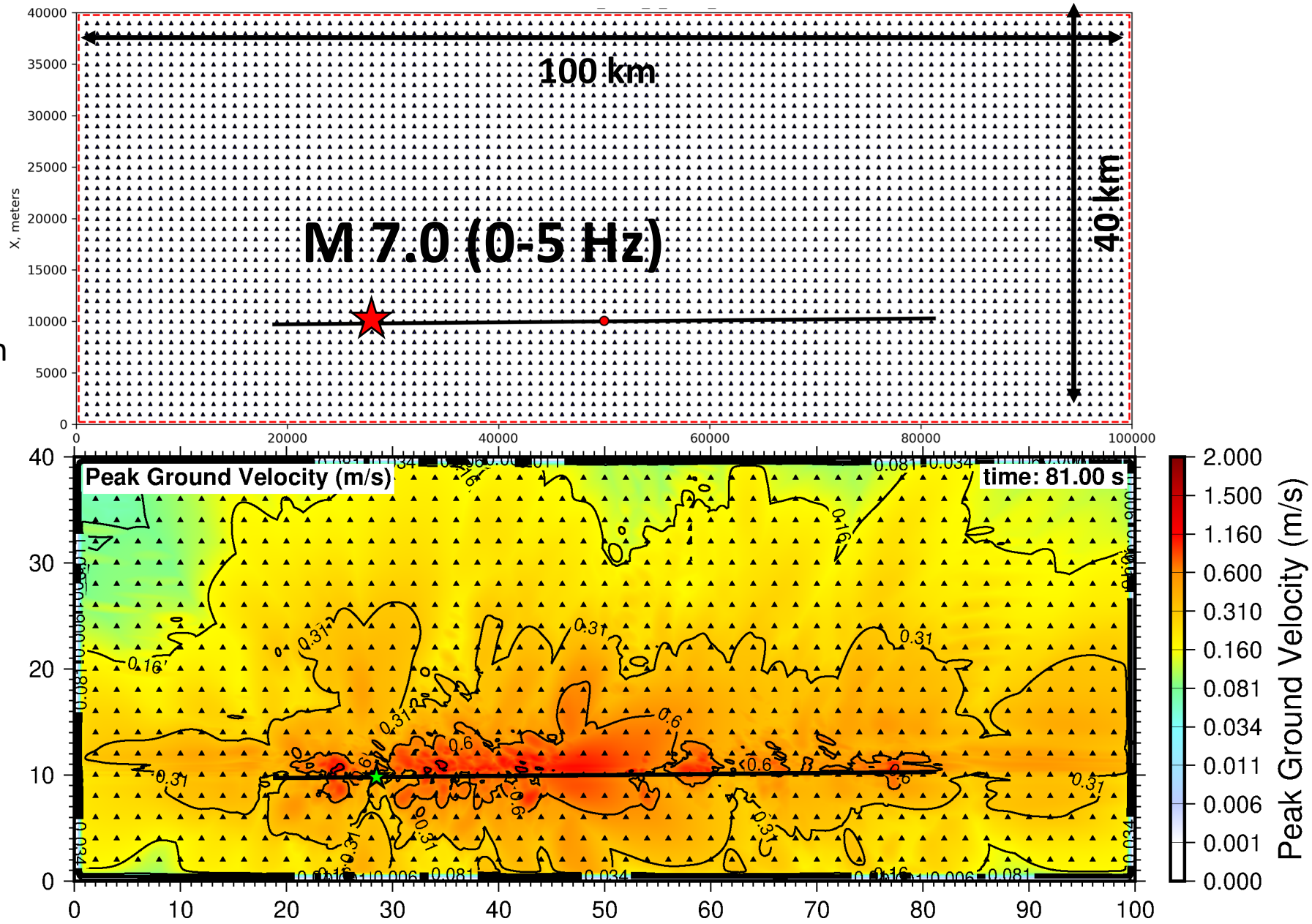
EXASCALE COMPUTING PROJECT

Ground motion model and computational domain

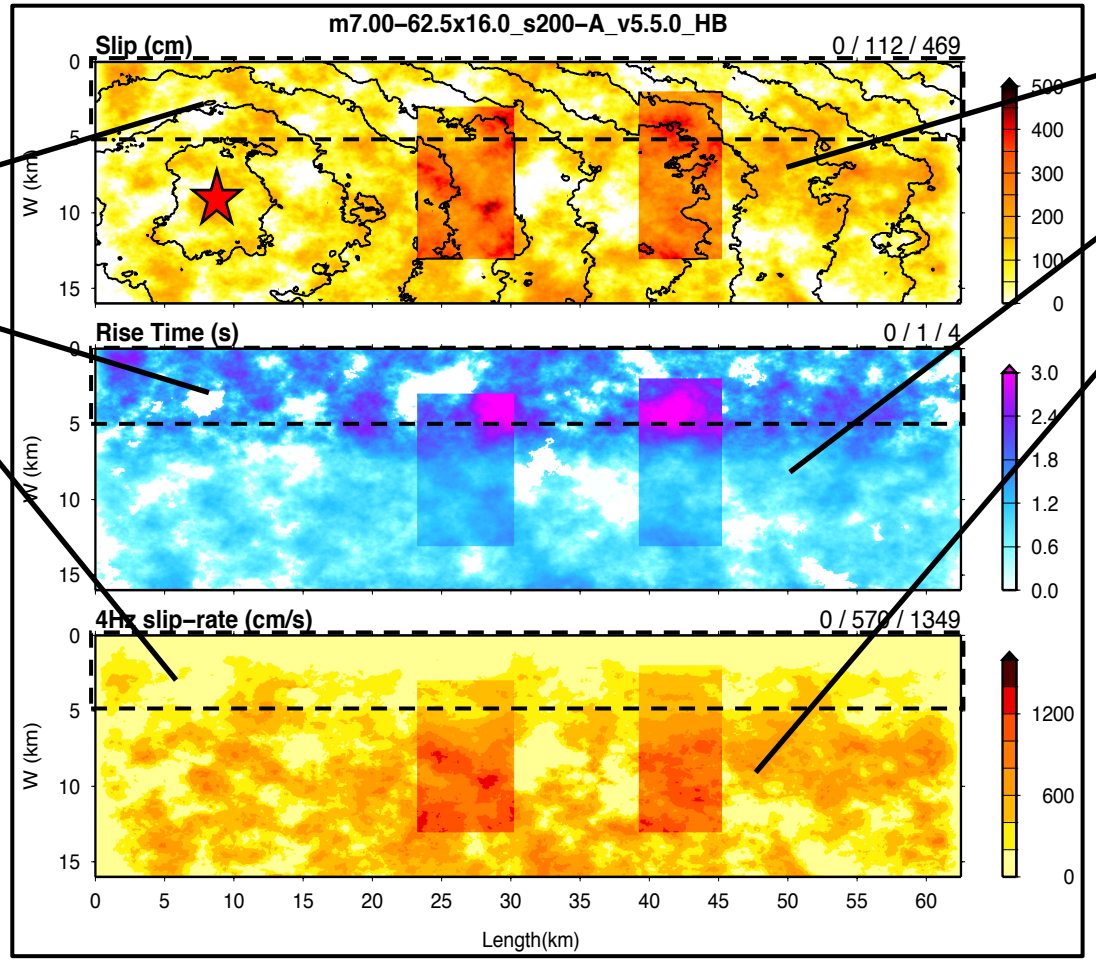
- Domain
  - 100 km x 40 km x 30 km (Depth)
  - Minimum shear wavespeed, vsmin = 320 m/s
  - Minimum grid spacing, hmin = 8 (two mesh refinements)
  - Maximum frequency, fmax = 320/(8*8) = 5.0 Hz at 8 PPW
- Earth model – Generic Open Basin
  - Sloping edge dx/dz = 200/600, dip ~ 81°
- Source Model
  - M_W 7.0 rupture, fault dimensions: 62.5 km x 16 km
  - Vertical strike slip, dip = 90 °
  - Z_{TOR} = 0. (depth to top-of-rupture)
  - Three slip distributions, same hypocenters
- Stations every 1 km (99 x 39 = 3861 stations)



Earthquake source model

Weak Zone (top 5 km)

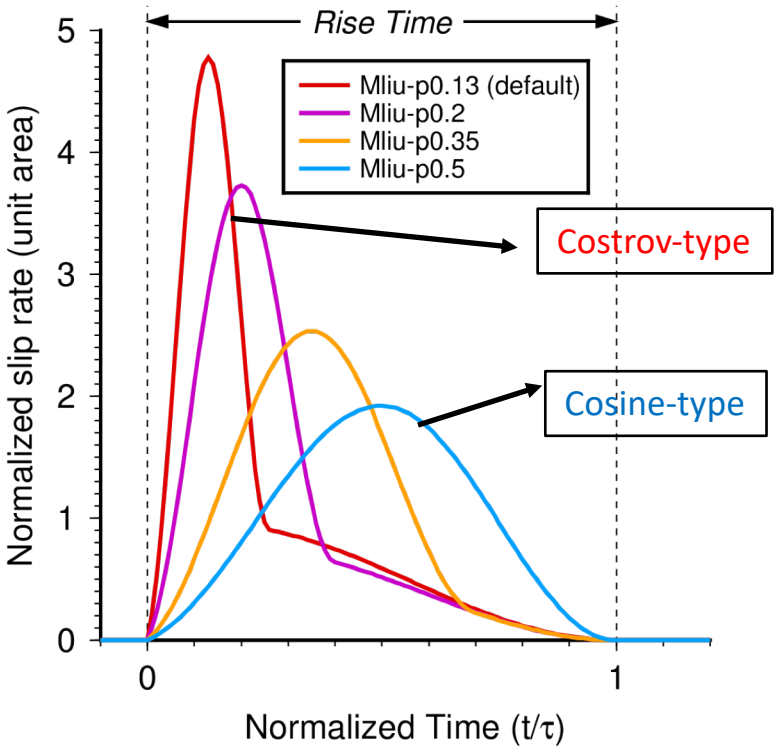
1. Longer Slip Rise Time
2. Lower Peak Slip Rate
3. Cosine-type Slip Rate Function

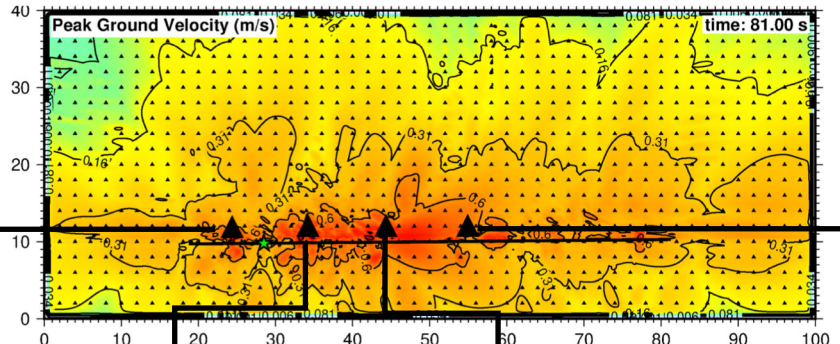


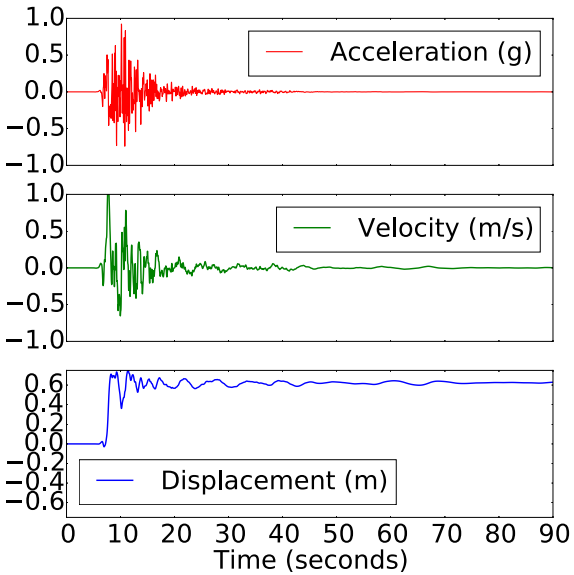
Concentrated Large-Slip Areas

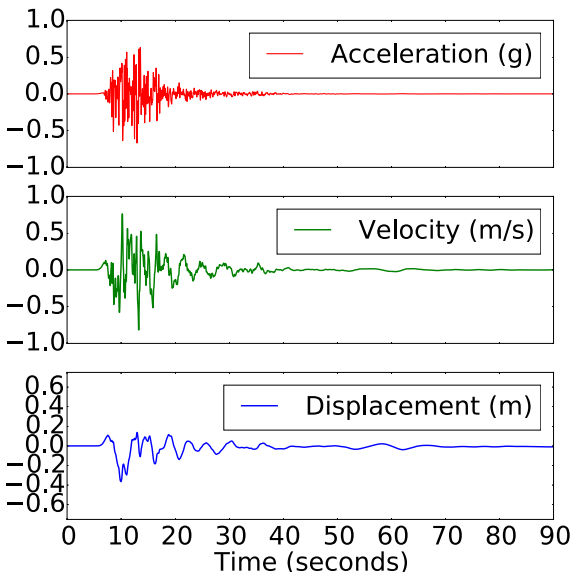
1. Shorter Slip Rise Time (below 5km)
2. High Peak Slip Rate (below 5km)
3. Kostrov-type Slip Rate Function (below 5km)

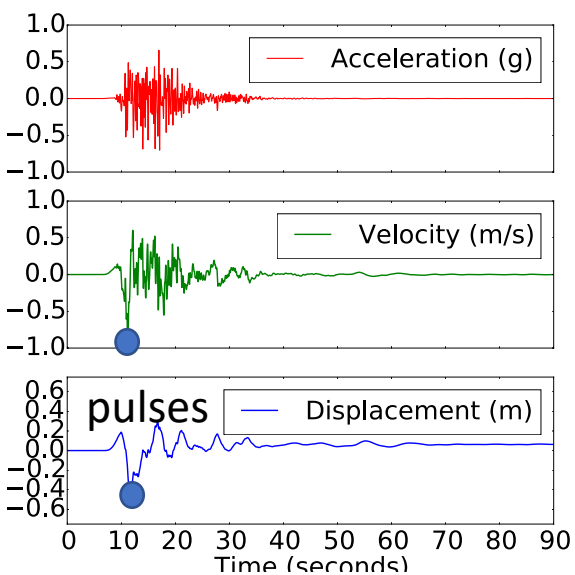
Slip Rate Functions

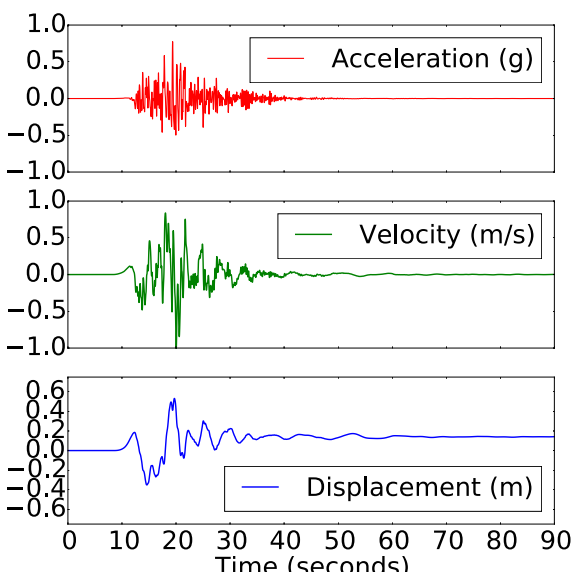


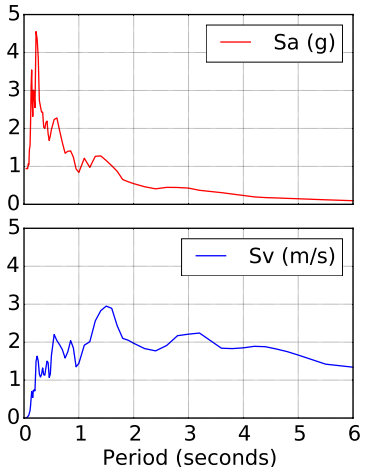

Peak Ground Velocity (m/s)
time: 81.00 s

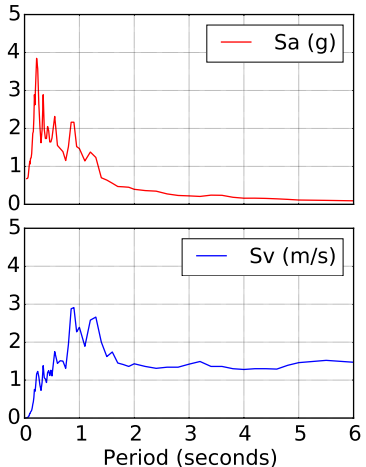

Acceleration (g)
Velocity (m/s)
Displacement (m)
Time (seconds)

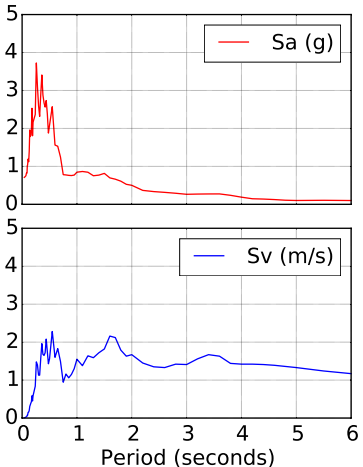

Acceleration (g)
Velocity (m/s)
Displacement (m)
Time (seconds)

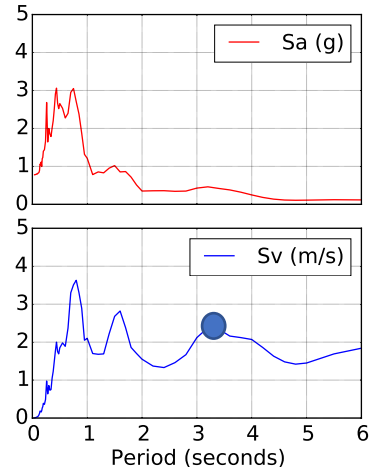

Acceleration (g)
Velocity (m/s)
pulses
Displacement (m)
Time (seconds)


Acceleration (g)
Velocity (m/s)
Displacement (m)
Time (seconds)

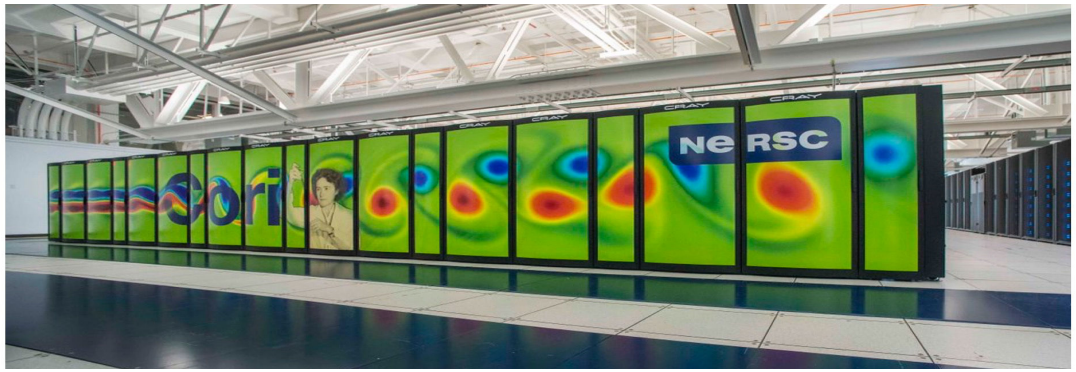

Sa (g)
Sv (m/s)
Period (seconds)


Sa (g)
Sv (m/s)
Period (seconds)


Sa (g)
Sv (m/s)
Period (seconds)

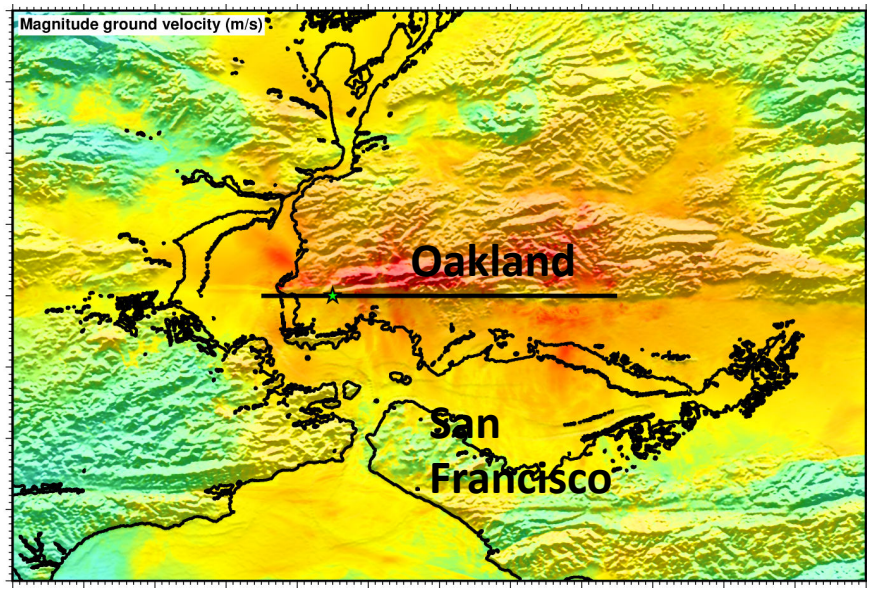

Sa (g)
Sv (m/s)
Period (seconds)

High-performance computing simulations

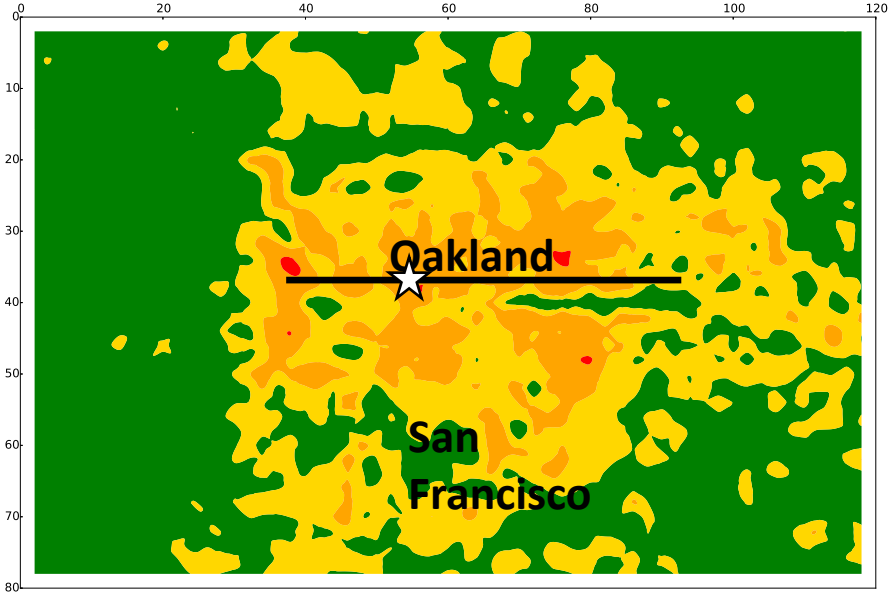


524,288 cores for one event simulation (5 Hz)

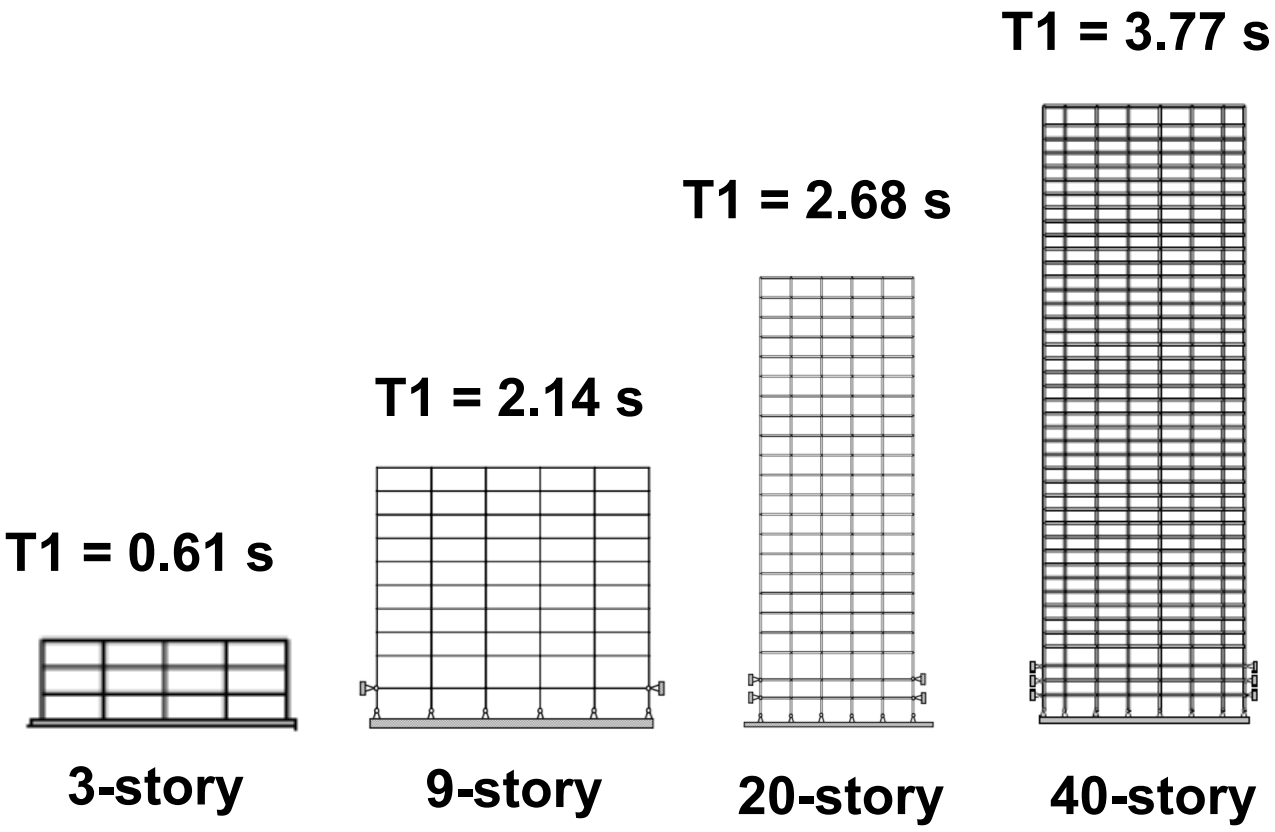
2,400 cores for a single building response analysis



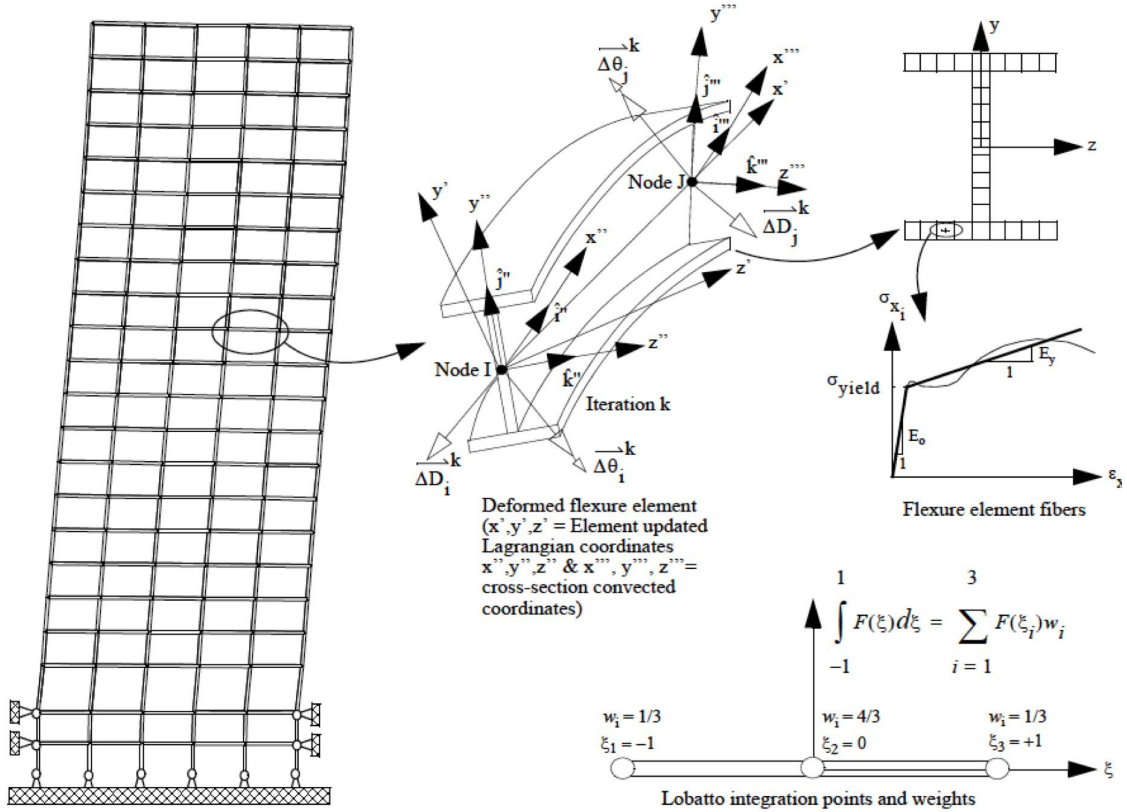
Python framework



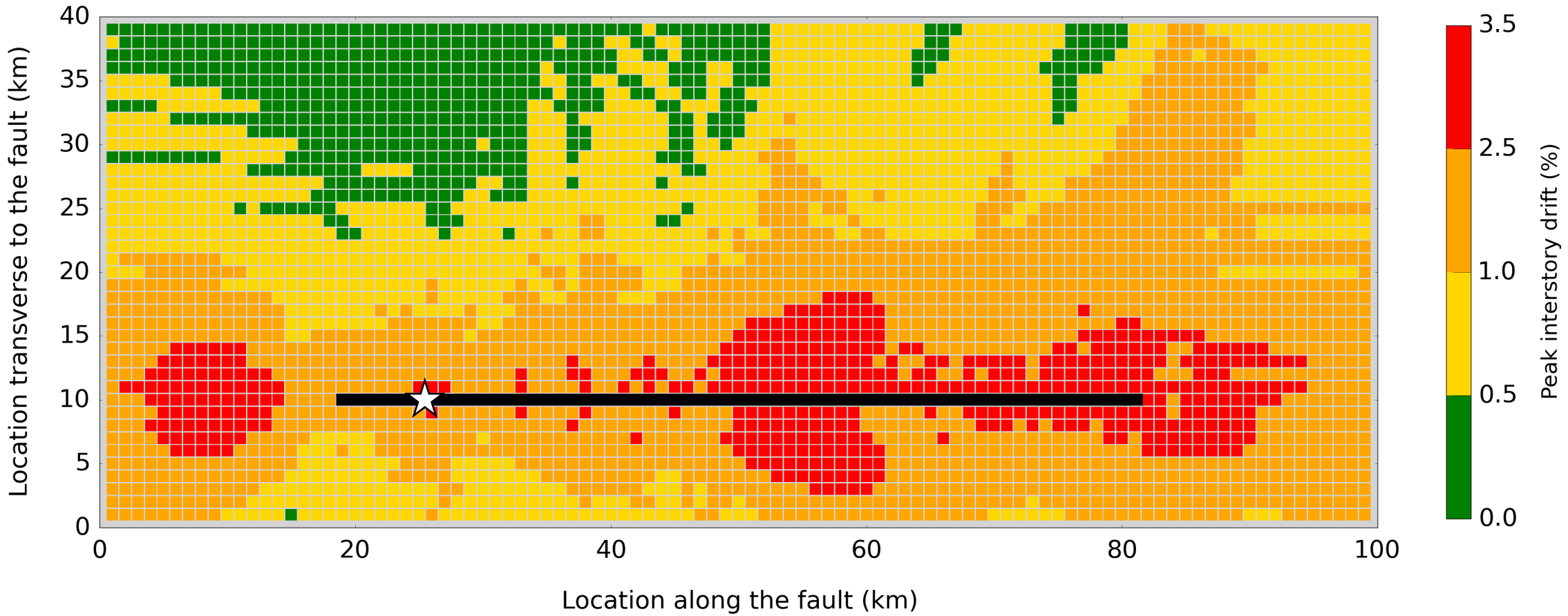
Building models in finite element based framework

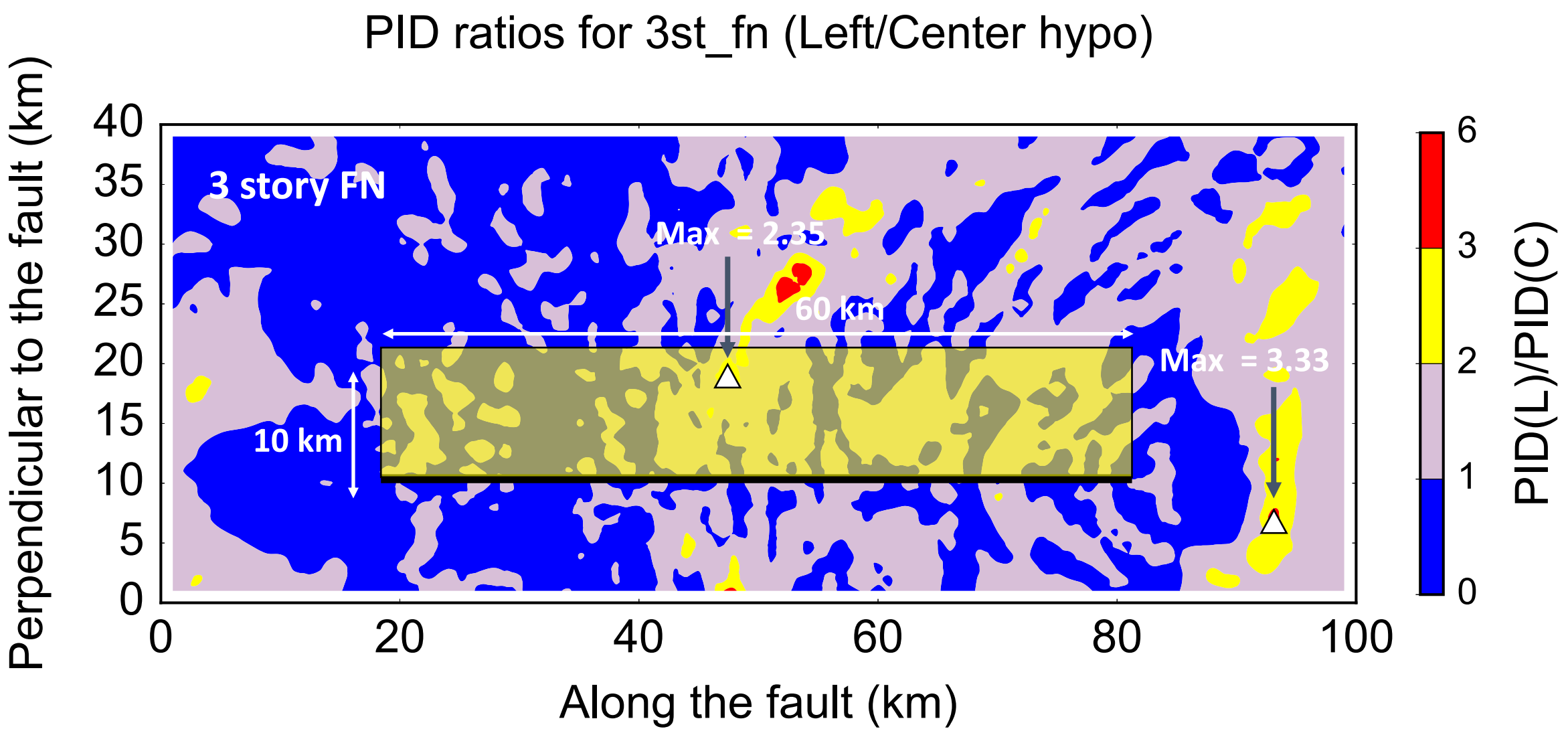


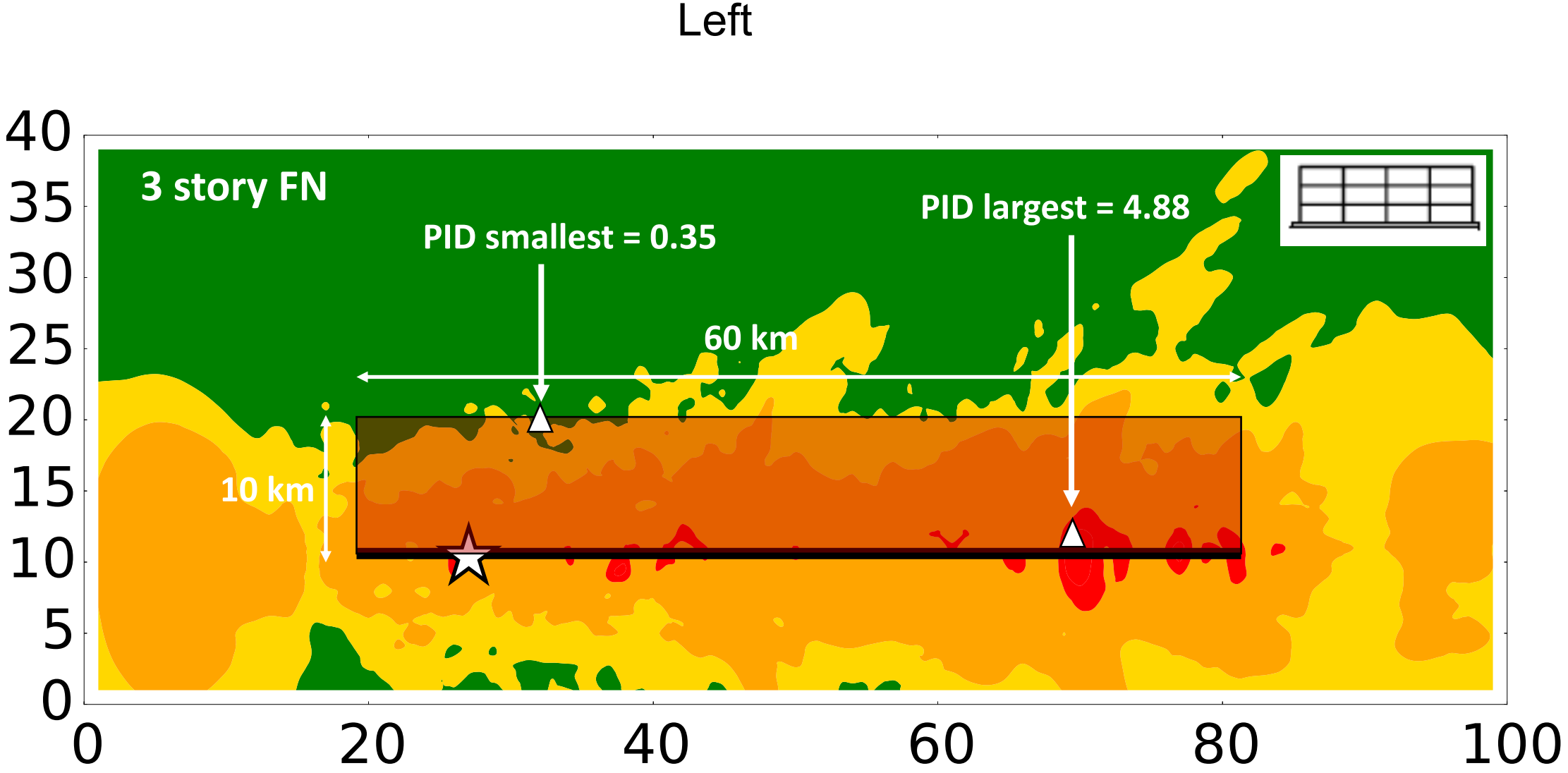
Canonical SMRF building models

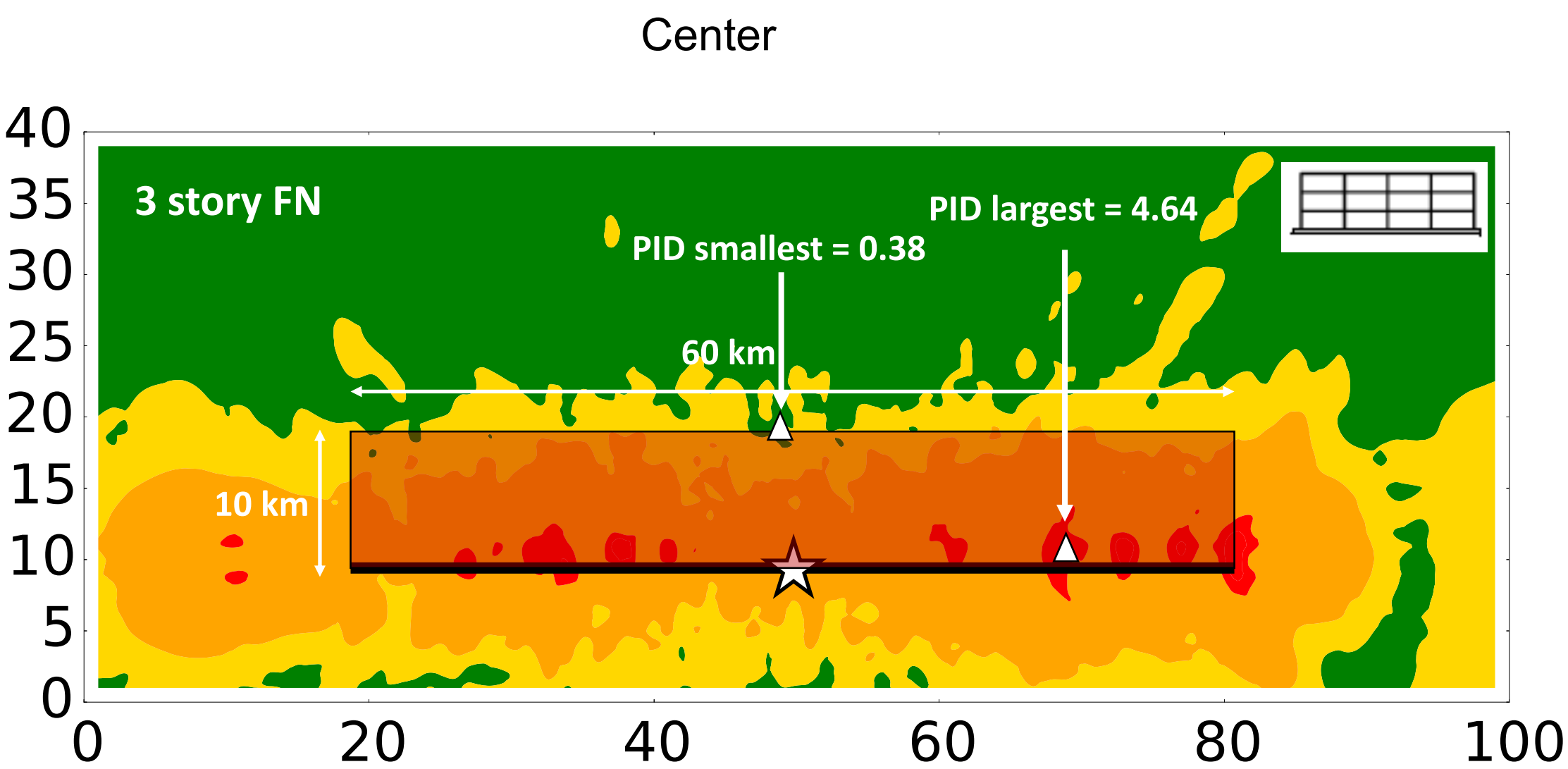


Finite deformation, fiber-based beam element modeling in Nevada code


9-story PID plot for M7.0 (FN, left hypocenter) motions
Location transverse to the fault (km)
Location along the fault (km)
Peak interstory drift (%)
0
5
10
15
20
25
30
35
40
0
20
40
60
80
100
0.0
0.5
1.0
2.5
3.5


PID ratios for 3st_fn (Left/Center hypo)
3 story FN
Max = 2.35
60 km
Max = 3.33
10 km
Perpendicular to the fault (km)
Along the fault (km)
PID(L)/PID(C)
0
5
10
15
20
25
30
35
40
0
20
40
60
80
100
0
1
2
3
6


Left
3 story FN
PID smallest = 0.35
PID largest = 4.88
60 km
10 km
0
5
10
15
20
25
30
35
40
0
20
40
60
80
100


Center
3 story FN
PID smallest = 0.38
PID largest = 4.64
60 km
10 km
0
5
10
15
20
25
30
35
40
0
20
40
60
80
100

Spectral acceleration shows better correlation with drift

- Synthetic ground motions are within 10 km off the fault
- Real records are all from the near-fault locations
- Spectral acceleration at the building's first mode period shows a good correlation with the building's seismic demand