CITY-SOIL INTERACTION IN THE VALLEY OF MEXICO: AMPLIFICATION AND LONG DURATION GROUND MOTION

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1 Instituto de Ingeniería-UNAM

2 Centro Nacional de Prevención de Desastres

Outline

- Introduction
- City-Soil Interaction
  - Central Mexico and Valley of Mexico Velocity Model
  - Mexico City Model
  - Simulations and Results
- Conclusions

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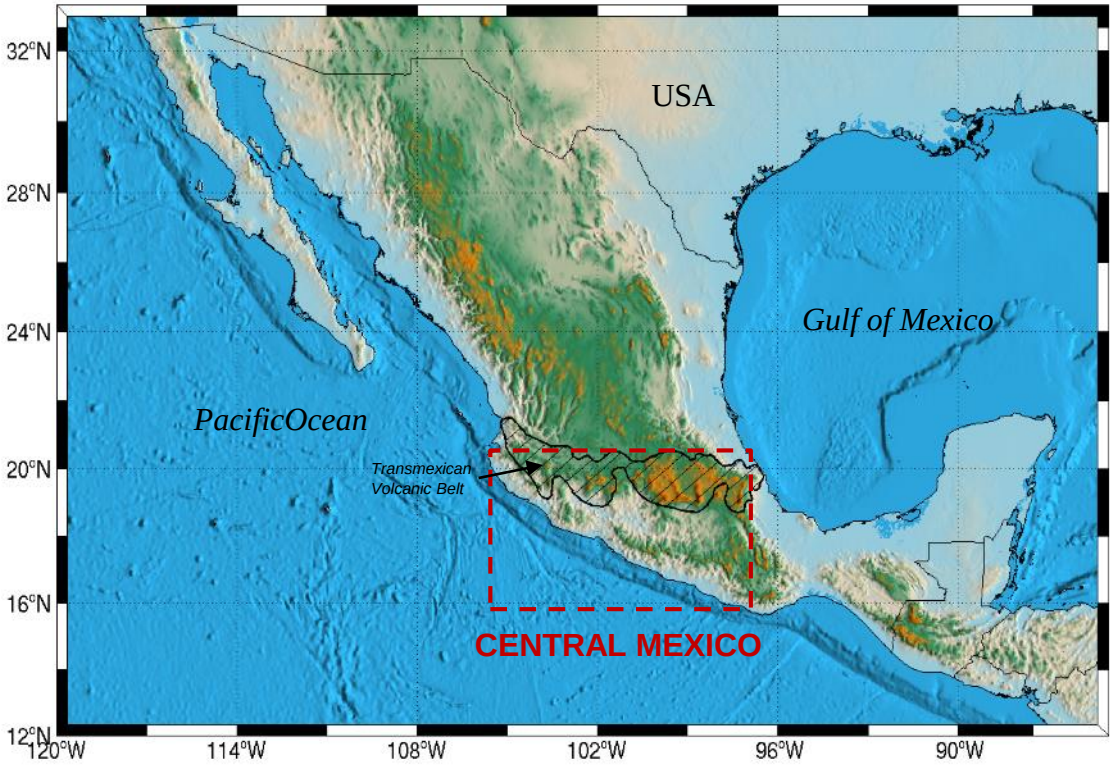
Introduction



Central Mexico:

- More than half the population lives in this region
- Holds most of the infrastructure of the country

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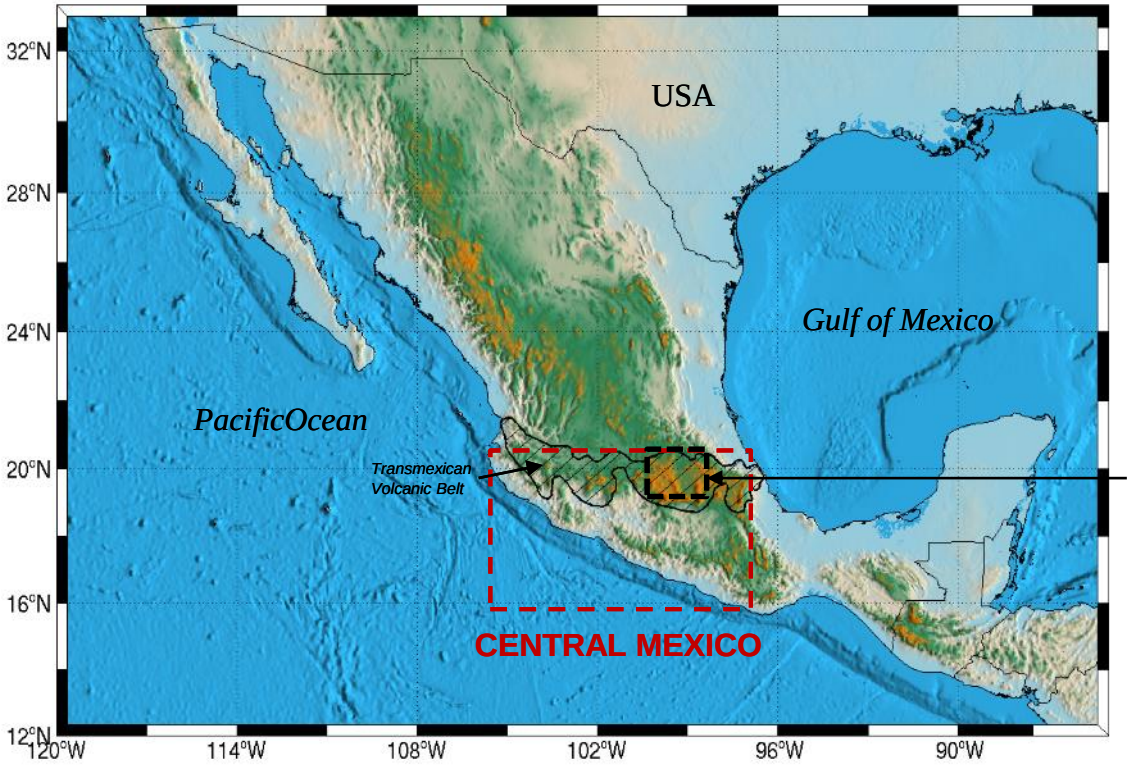
Introduction



Central Mexico:

- More than half the population lives in this region
- Holds most of the infrastructure of the country

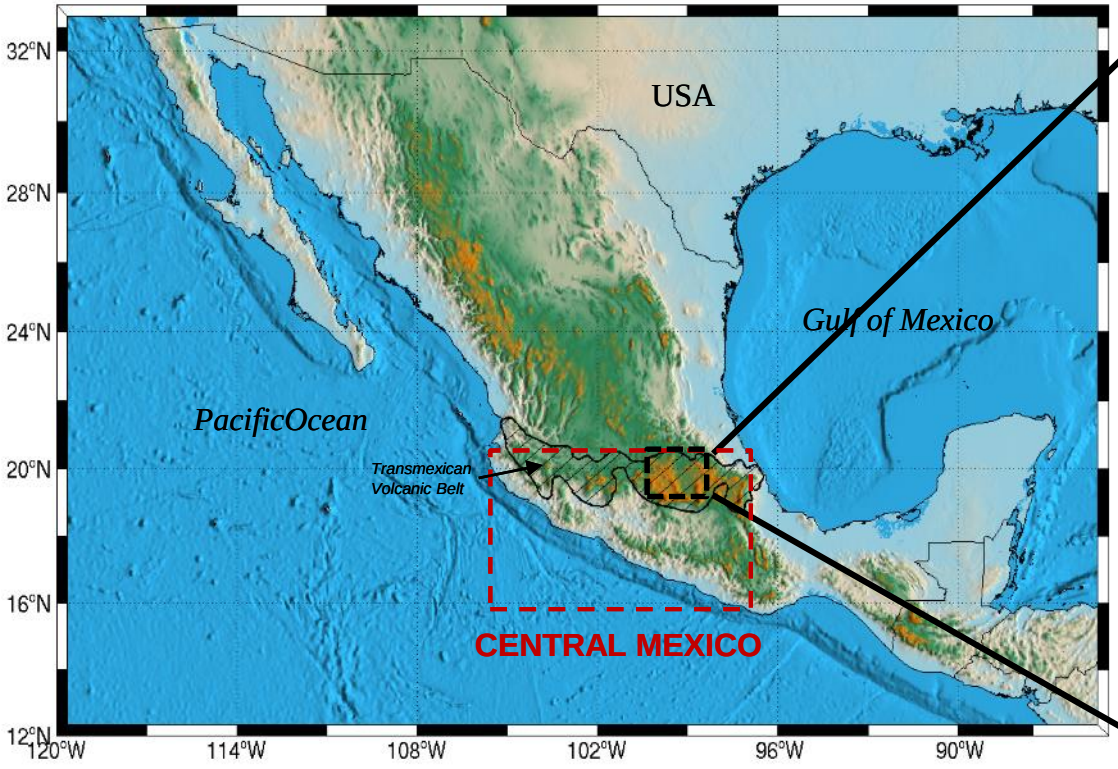
Valley of Mexico (Mexico City):

- More than one third of Mexico's population lives in this region.
- More than one third of the GDP is generated *here*.

To understand the natural hazards is a priority

Introduction

Most of Mexico City is located in a former lake



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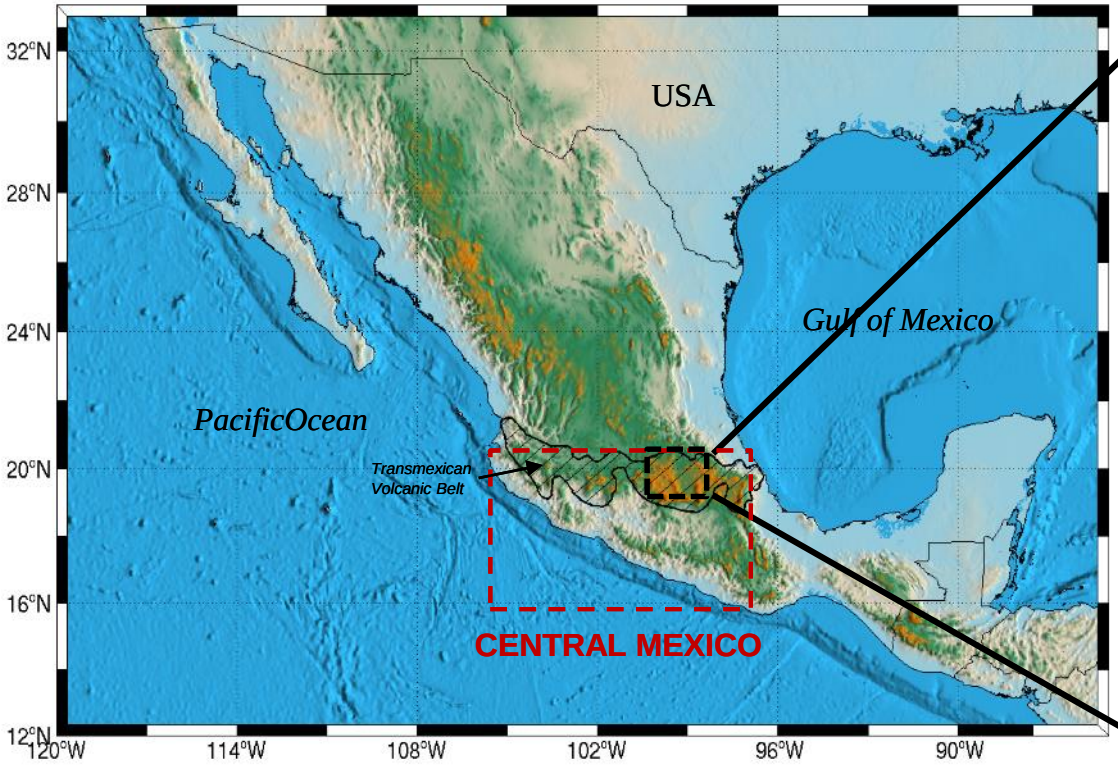
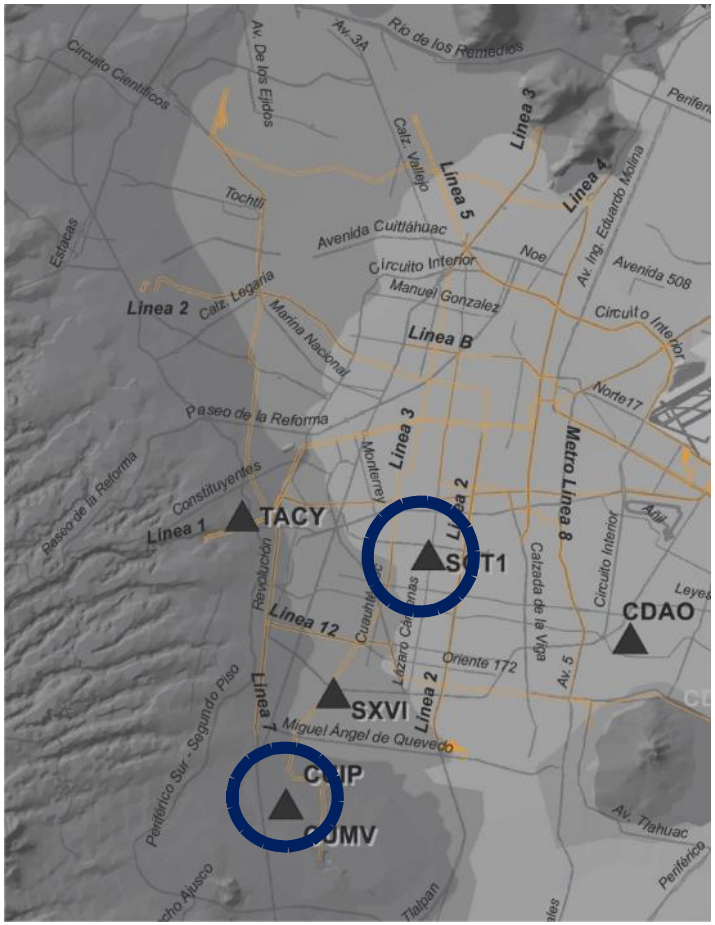


Unusual site effects

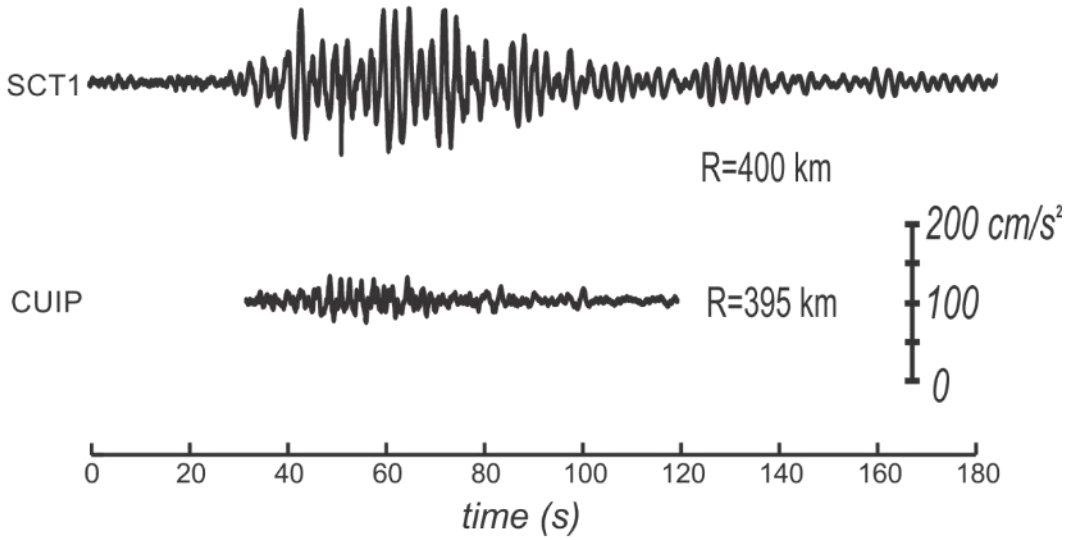
Introducción

Ground Motion Amplification and Long Duration



Geotechnical Zones

Hills (rock) *Transition* *Lake*



Acceleration records for the Mw 8.0 September 19th Michoacan Earthquake. After Singh et al. (1988, BSSA). Instrumentation and data maintained by the Seismic Analysis and Instrumentation Team (II-UNAM).

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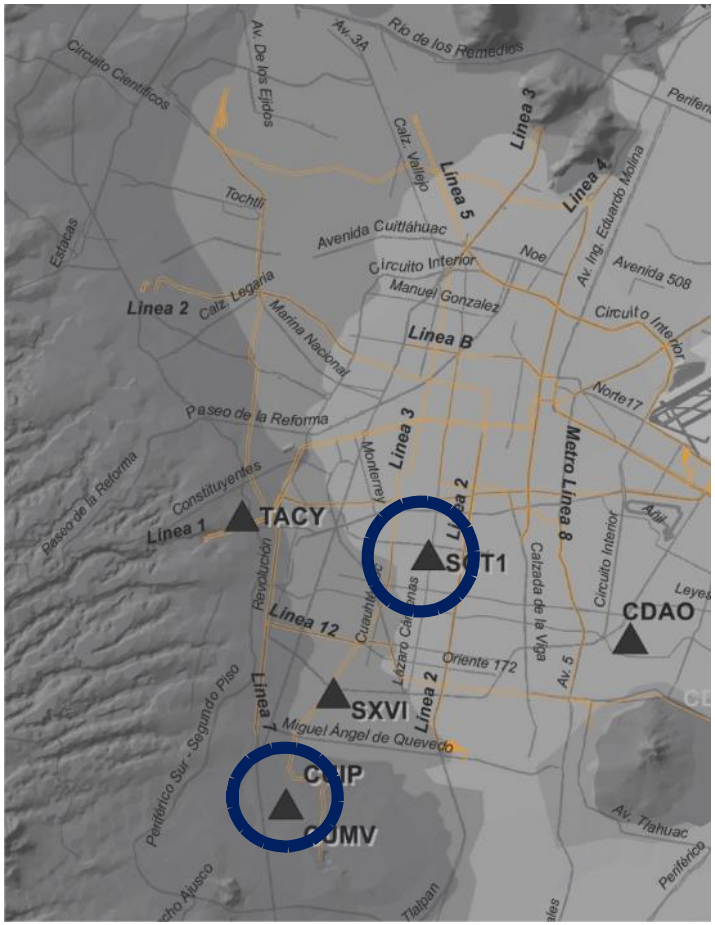
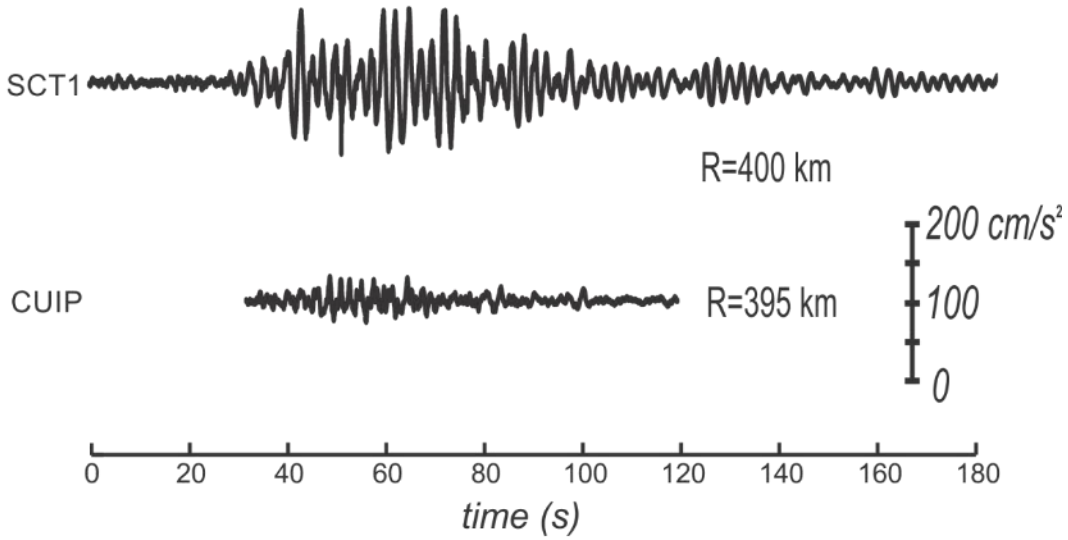


Geotechnical Zones

Hills (rock) *Transition* *Lake*

Reason:
IMPEDANCE



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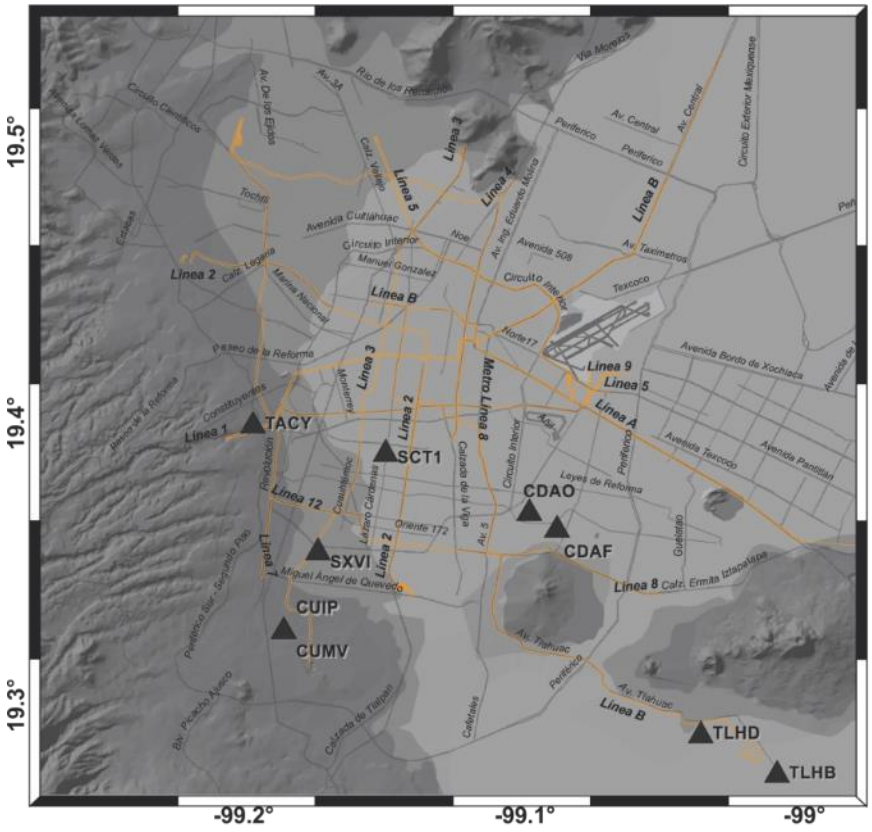

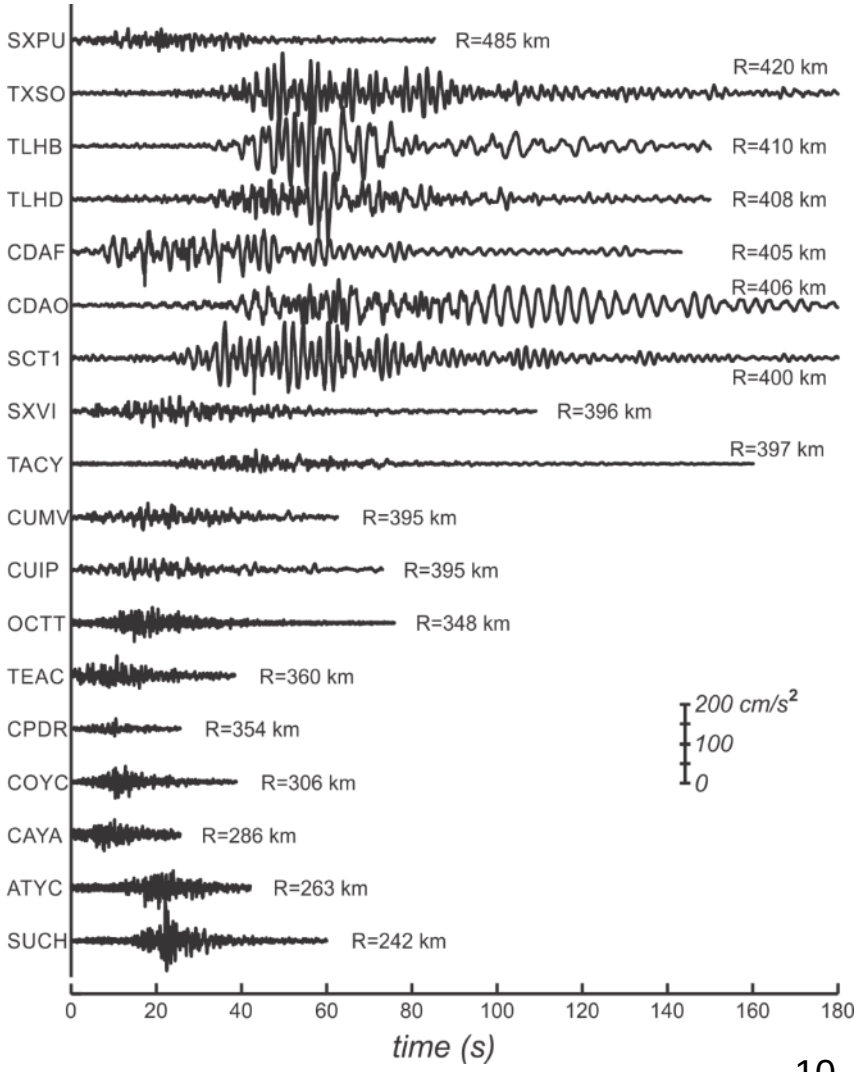

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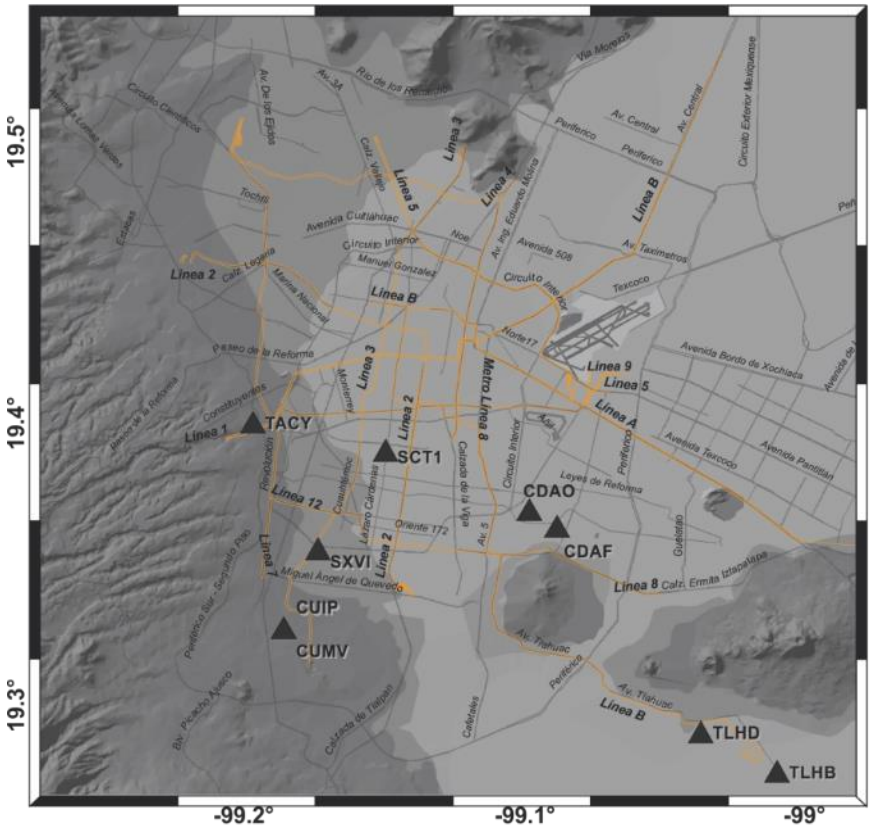

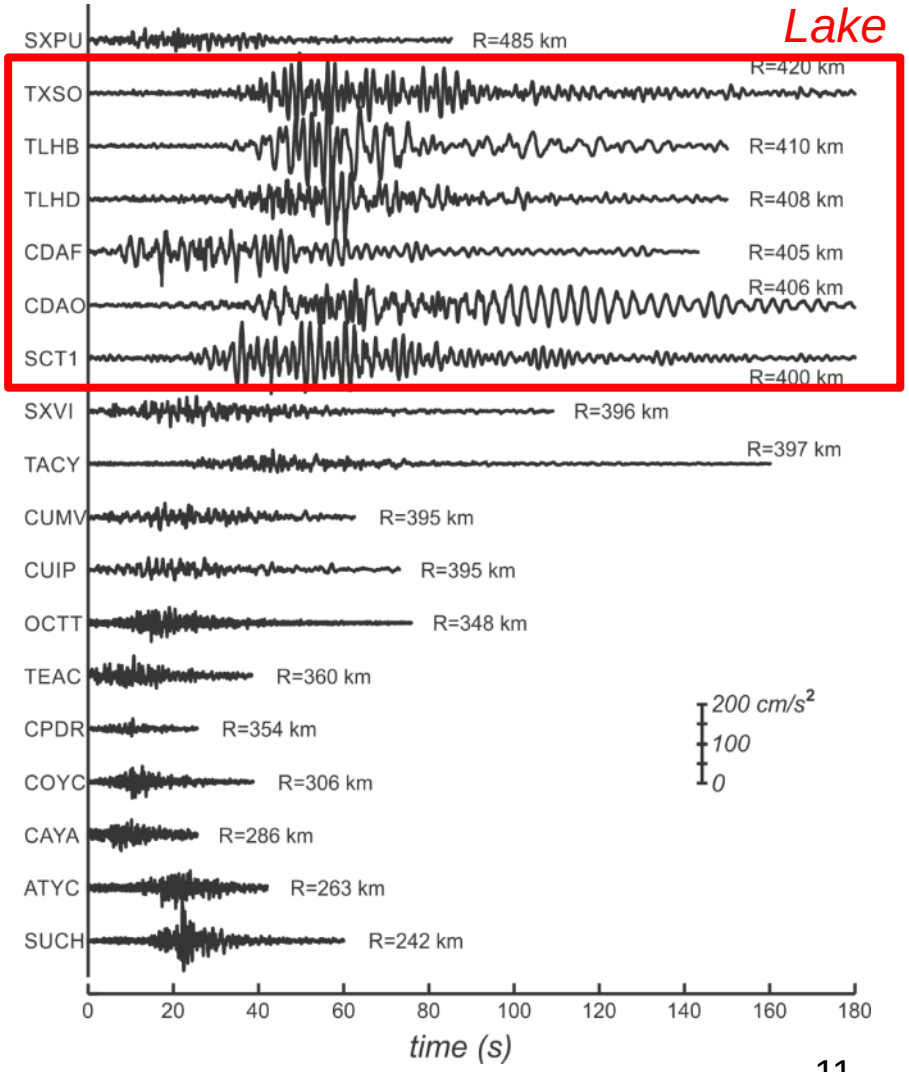

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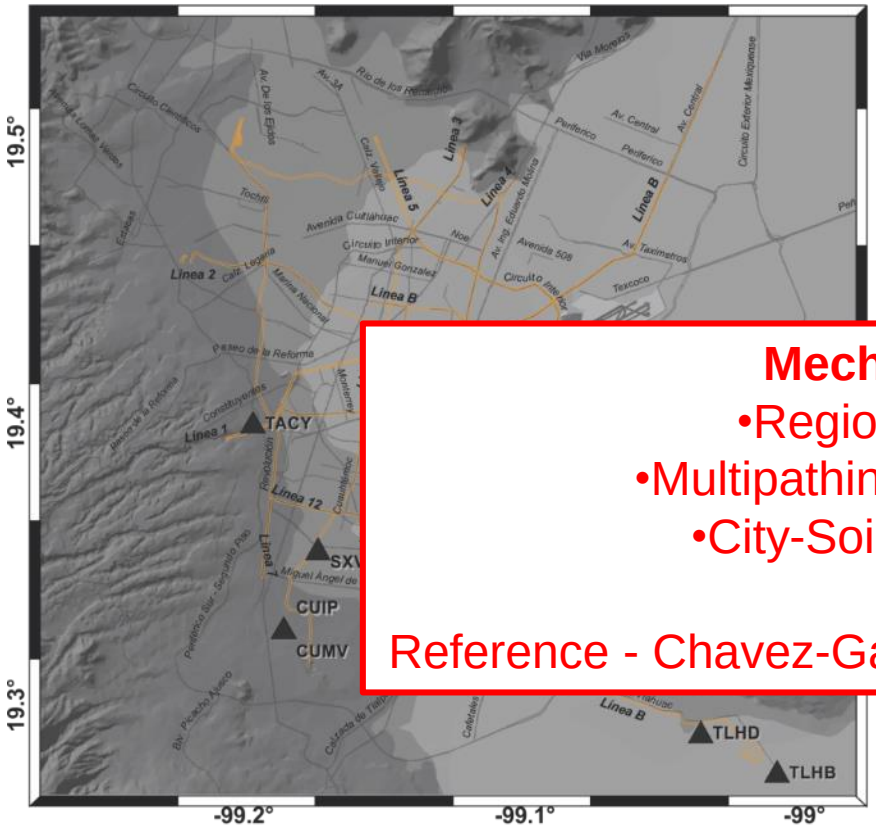

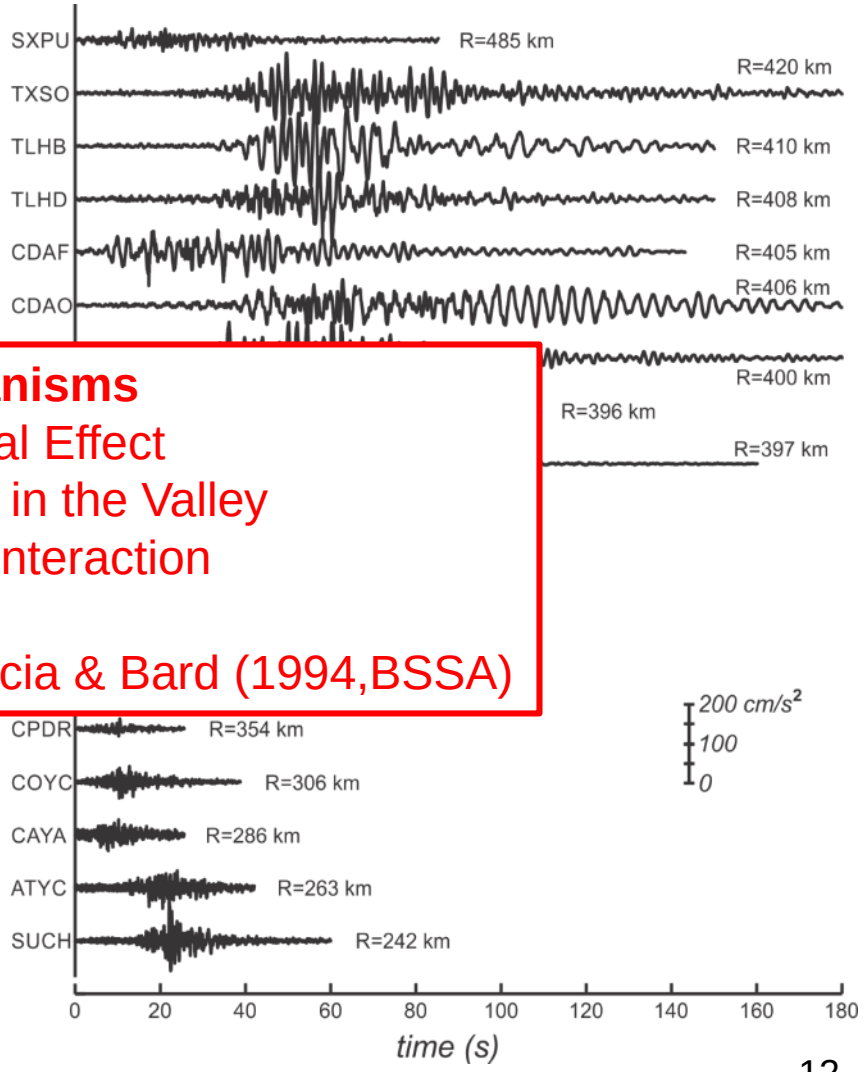

Mechanisms

- Regional Effect
- Multipathing in the Valley
- City-Soil Interaction

Reference - Chavez-Garcia & Bard (1994,BSSA)

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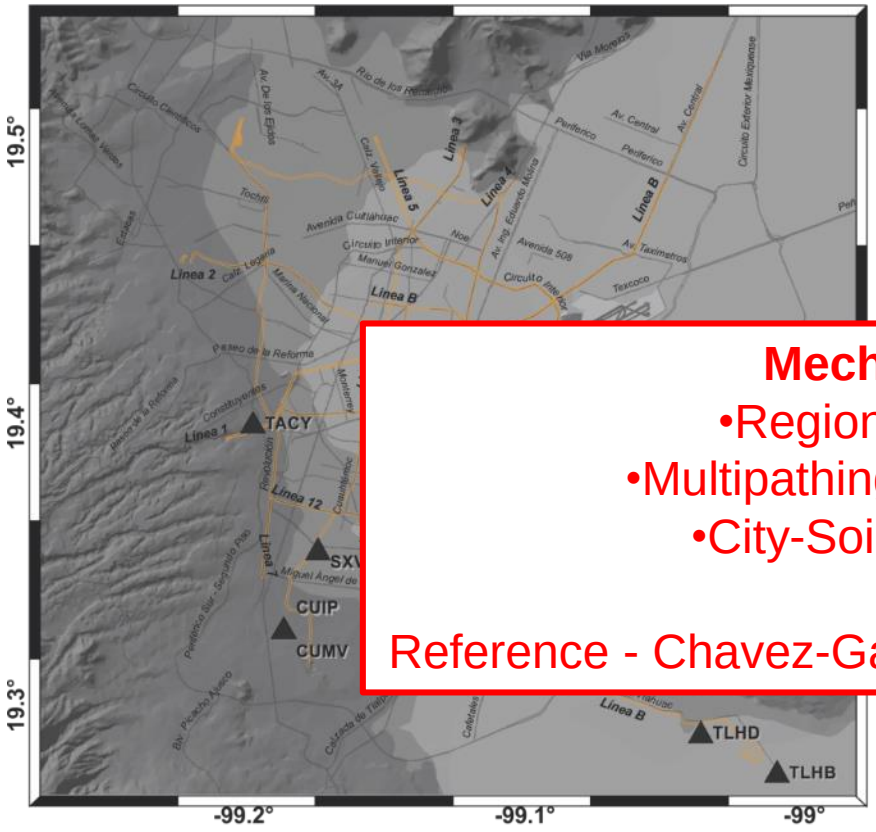

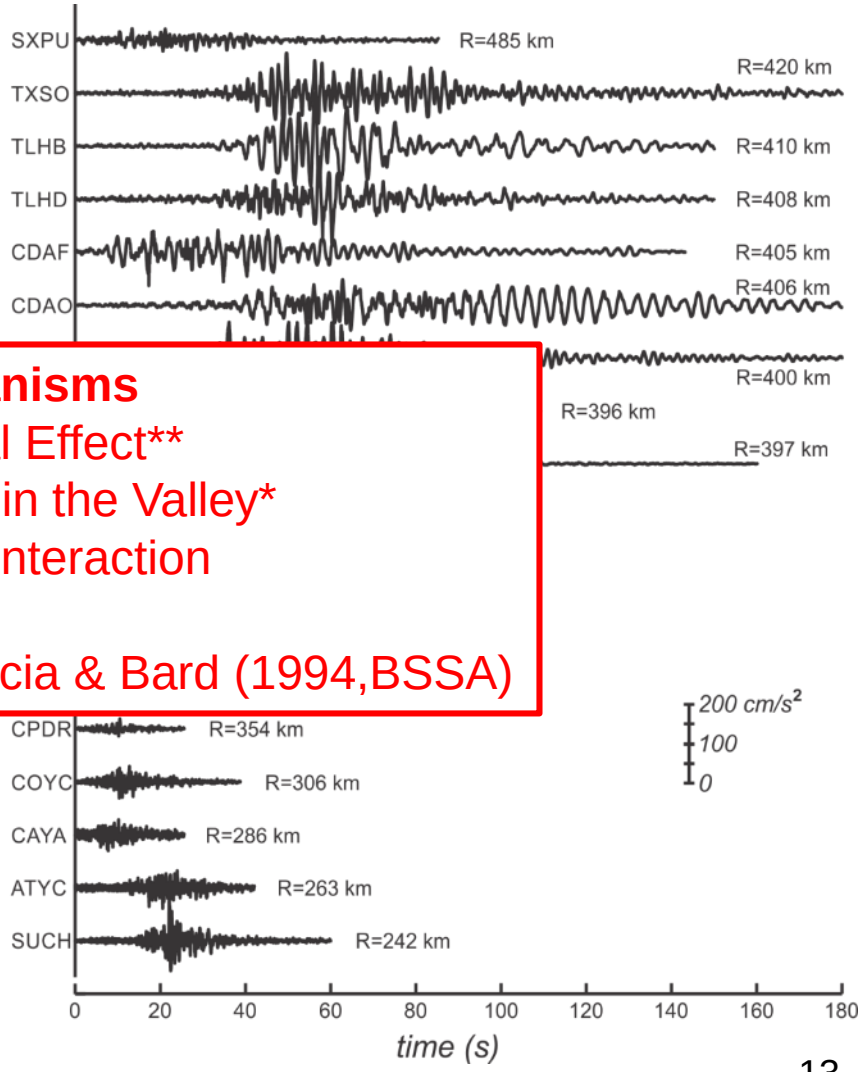

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- No consensus on the mechanism

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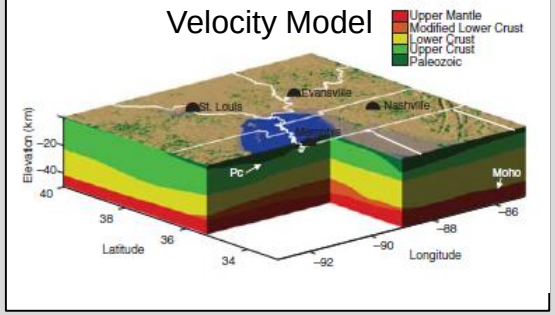
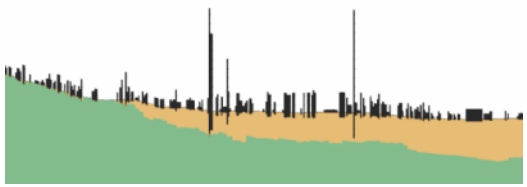
City-Soil Interaction

Input

Velocity Model



City Model



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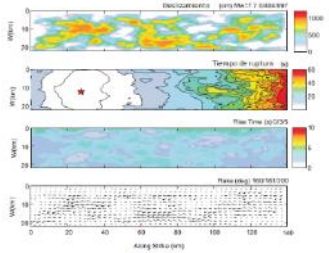


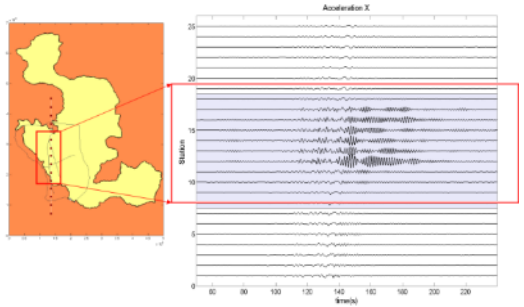
Methodology

Numerical Solution

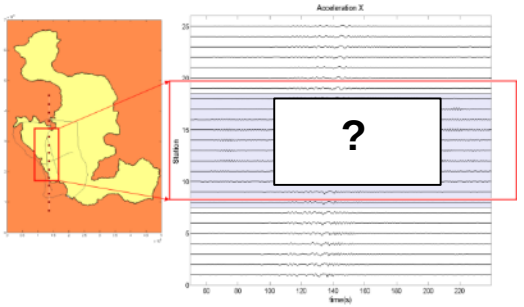
Hercules (Tu et al, 2006)
(MIZTLI and TONATIUH cluster
DGTIC & IE UNAM)

Output

No Buildings



Buildings



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City-Soil Interaction

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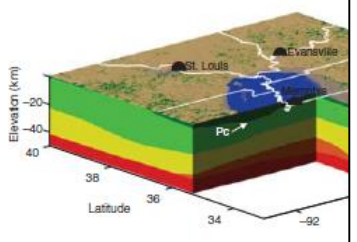
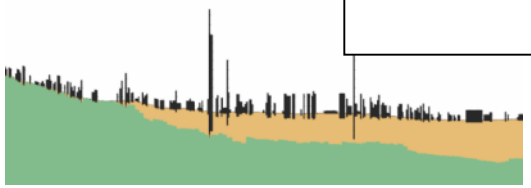
Velocity Model



City Model



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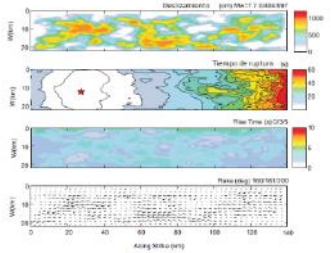
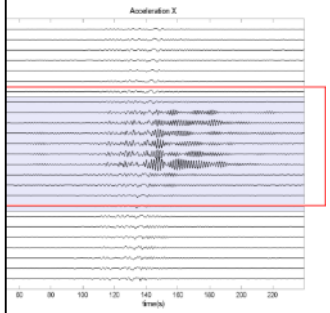


- Spatial Database Manager
- Hercules (Tu et al.,2006)
  - Linear Finite Elements
  - Rayleigh Damping
  - Paraxial absorbing boundries
  - Topography (Hartzell et al., 2010,BSSA)

Output

Buildings



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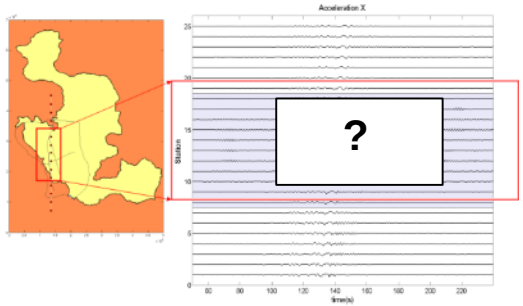

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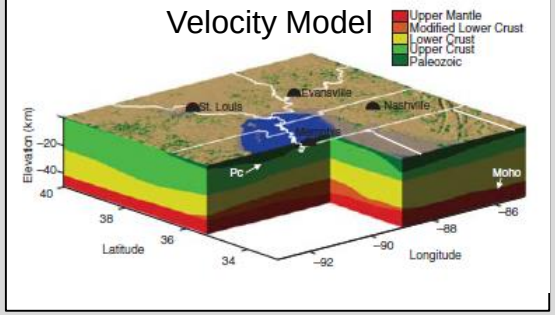

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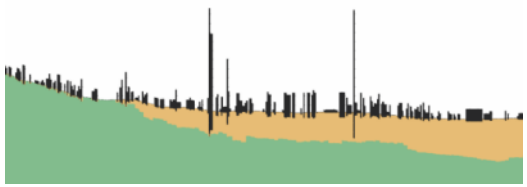

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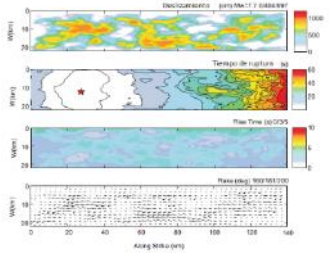

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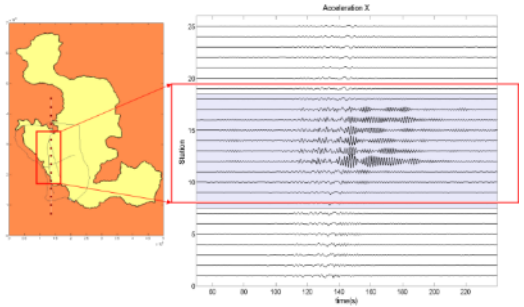

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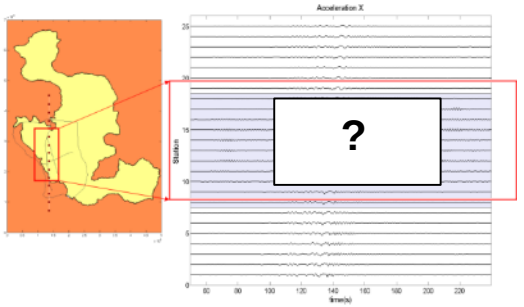

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City-Soil Interaction

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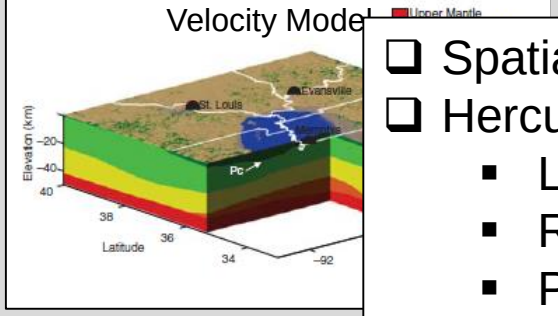
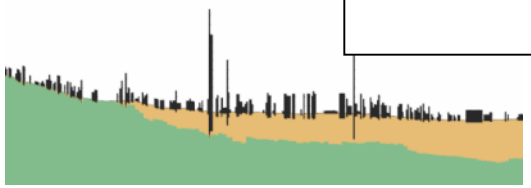


City Model



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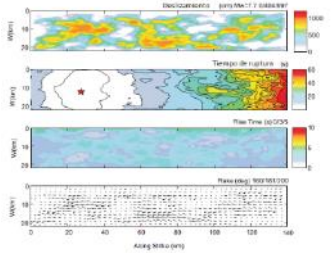

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- Hercules (Tu et al.,2006)
  - Linear Finite Elements
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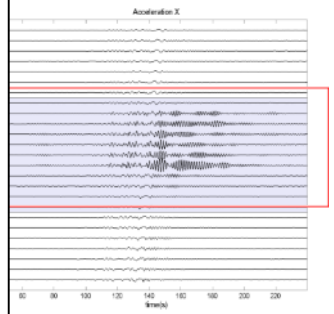

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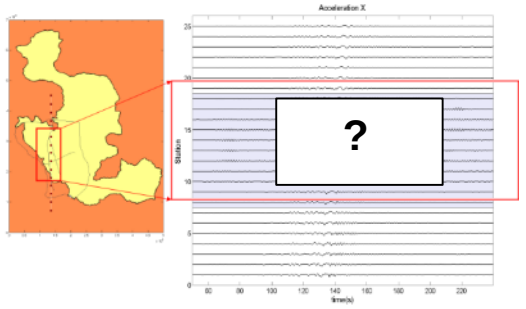

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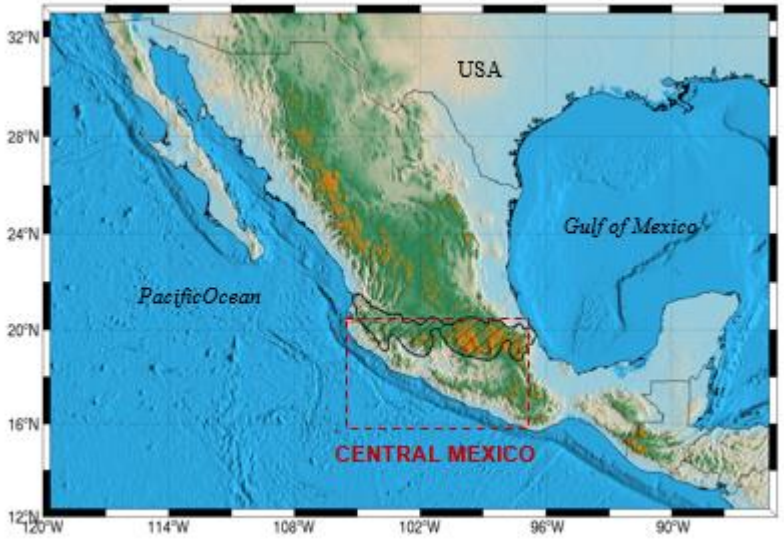
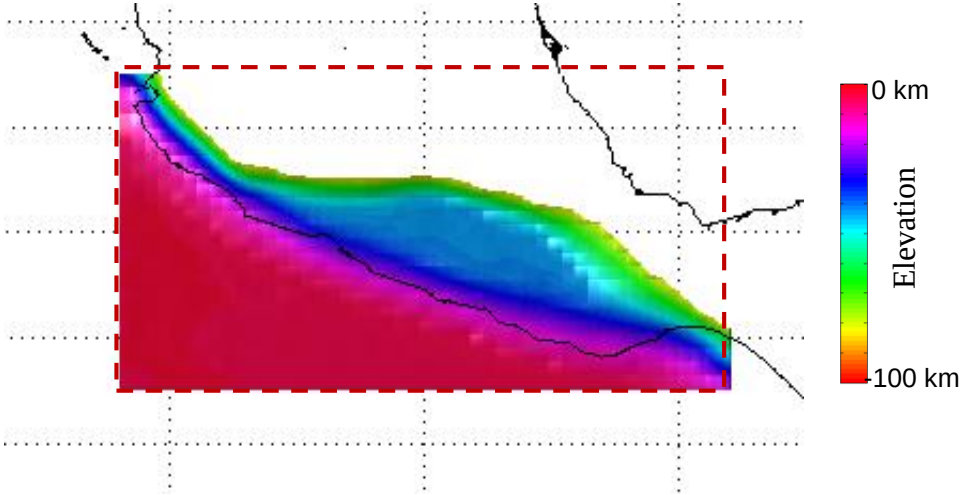
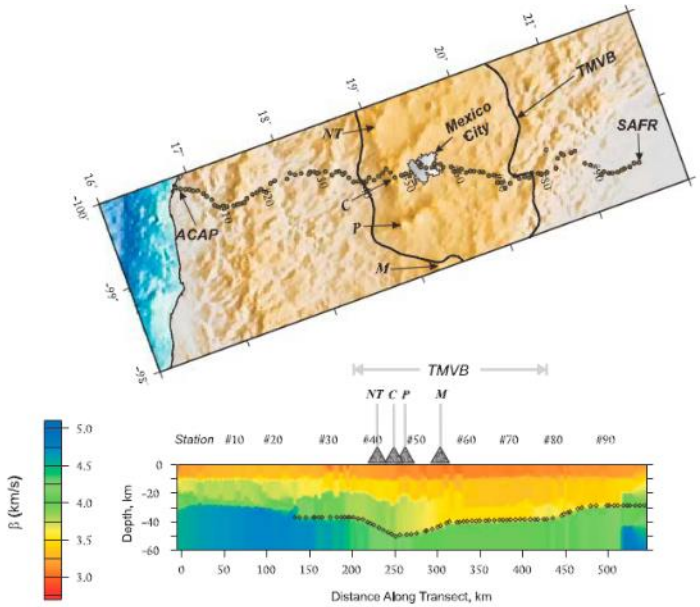
Central Mexico and Valley of Mexico Velocity Model



Model Extension



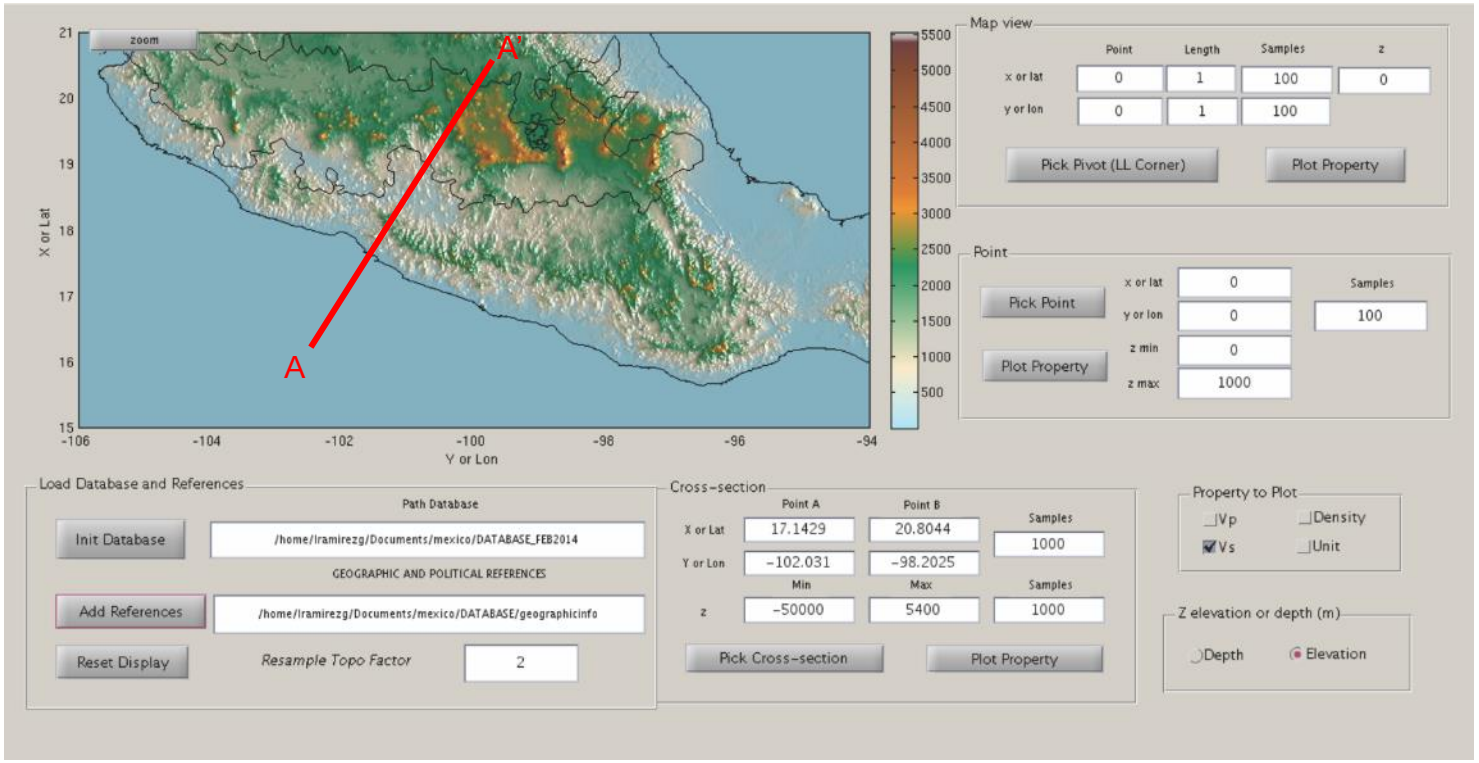


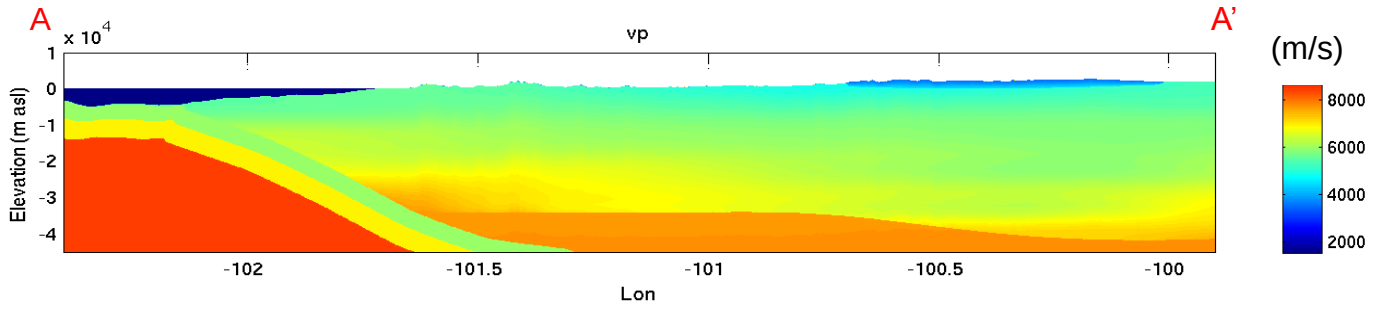
Tomography results (Iglesias *et al*., 2010)

Constrained with gravity and other geophyisical and geotechnical information (e.g. Espindola, 2001; Valdes & Meyer, 1996)

Central Mexico and Valley of Mexico Velocity Model

GUI CMVM





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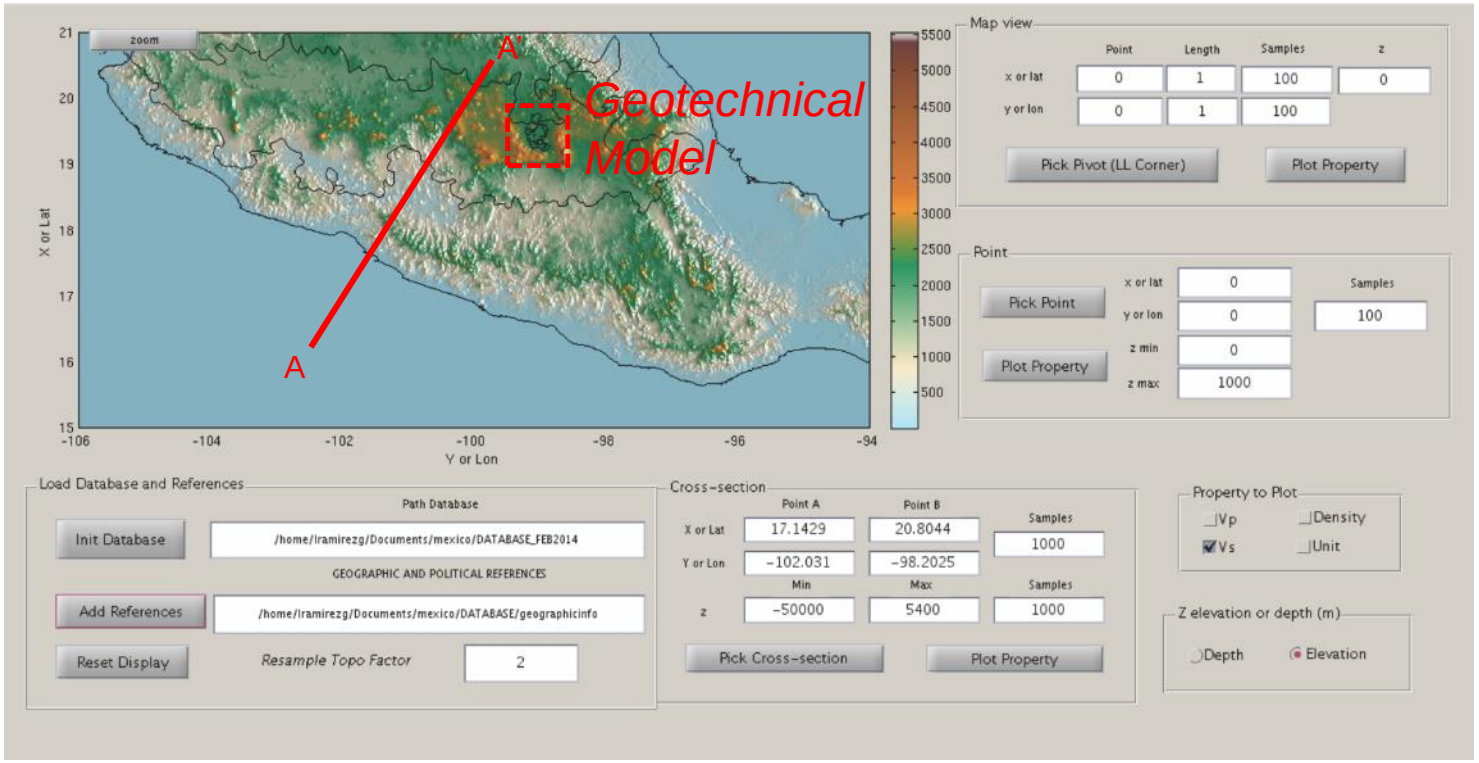
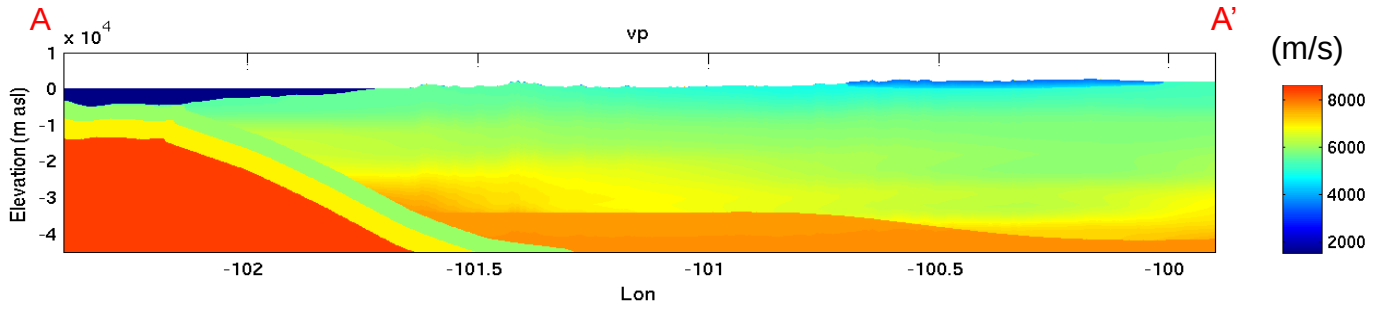
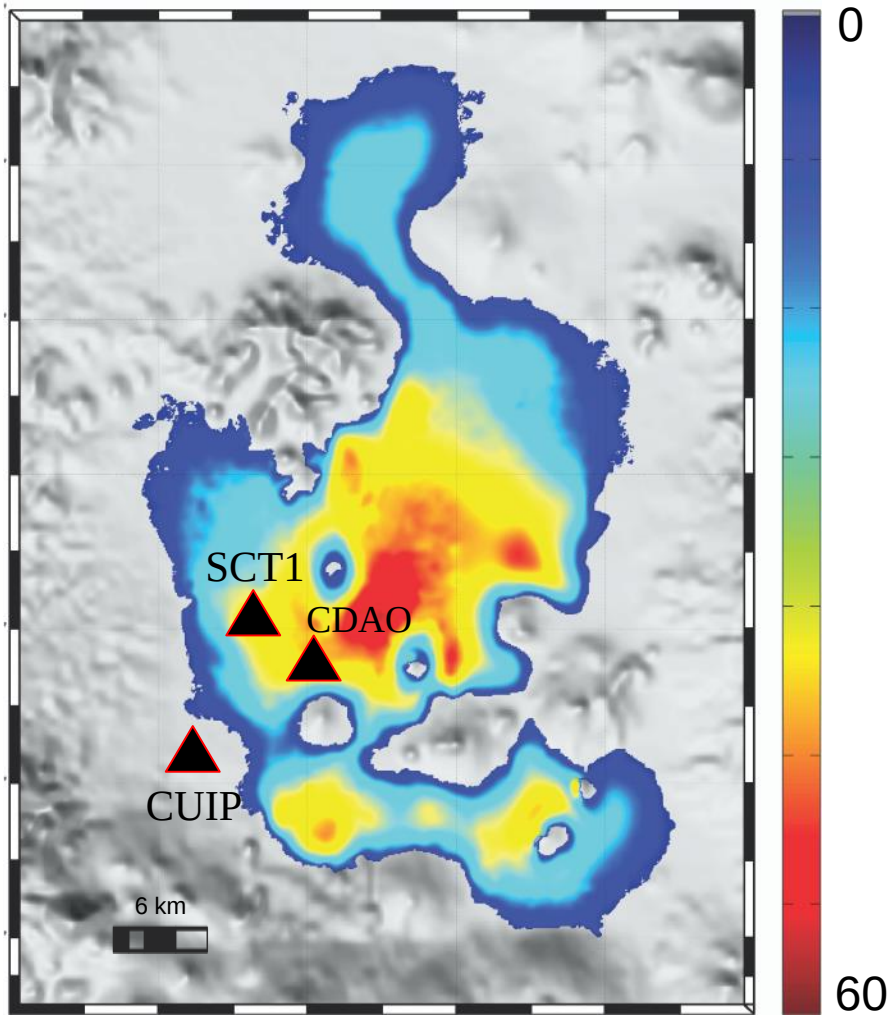




Central Mexico and Valley of Mexico Velocity Model

Clay/low velocity deposits thickness



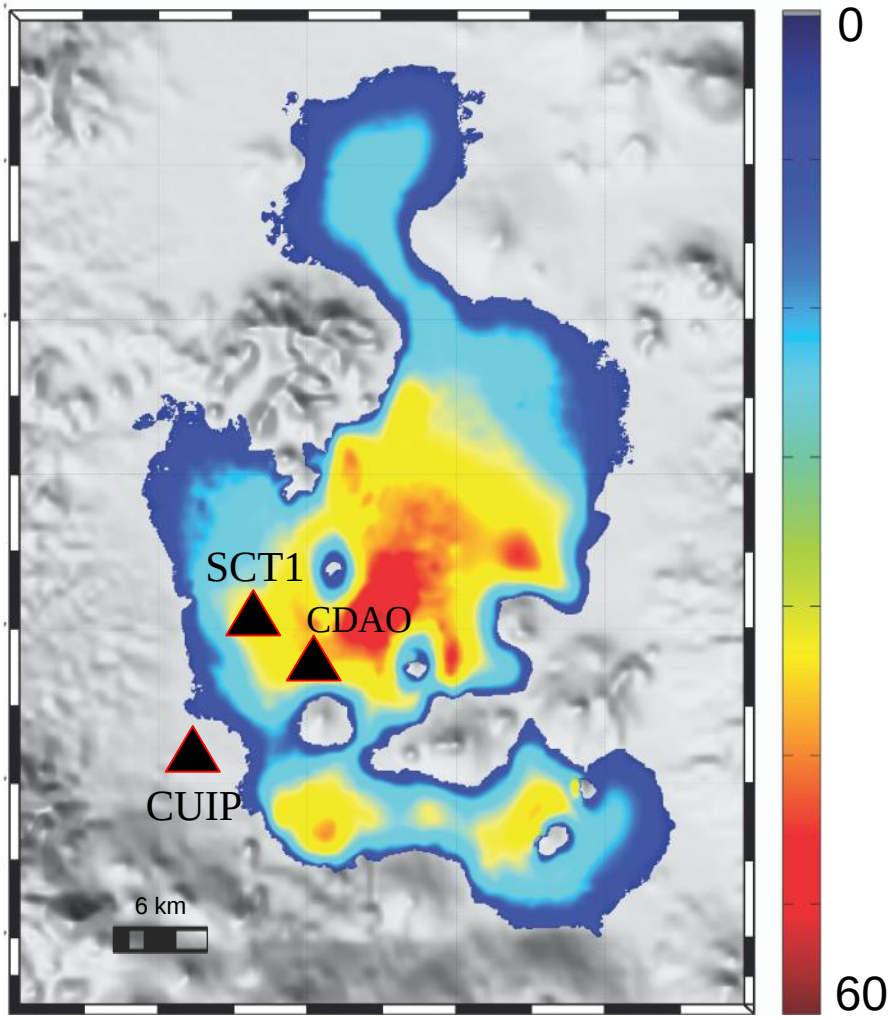
Model construction is based on:

- *Fundamentamental periods in the Lake*
- *A background mean profile*
- *15 profiles*

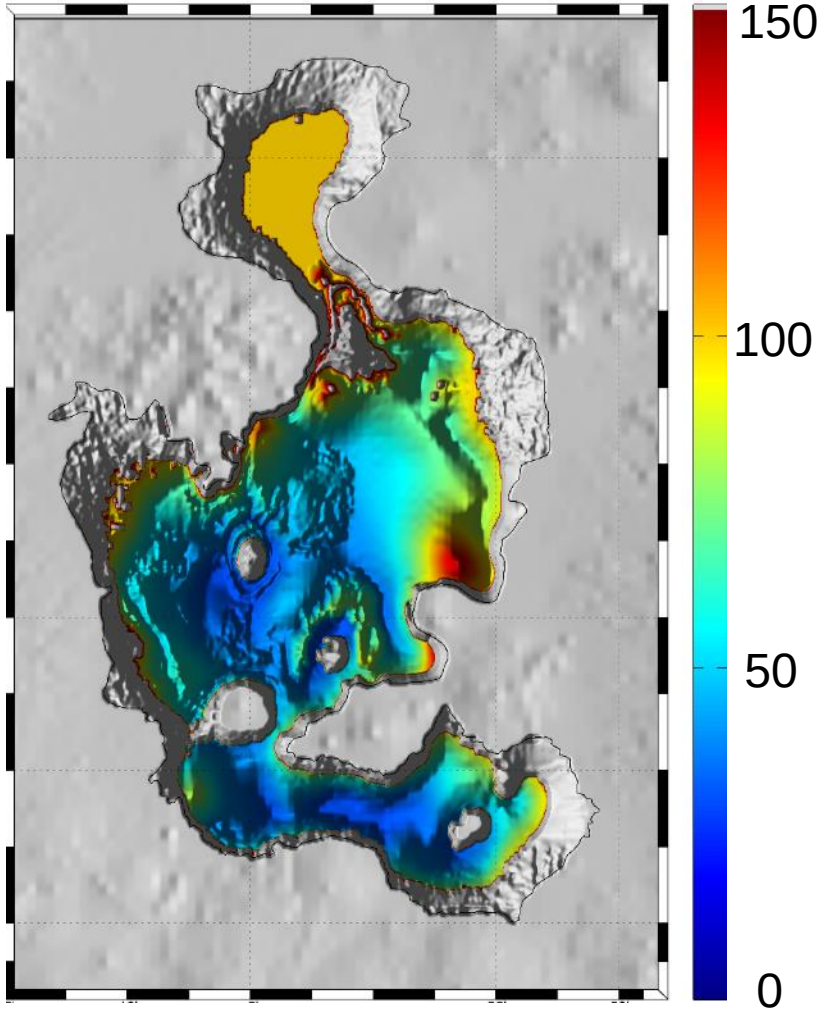
The information is used to generate a regular grid.

Central Mexico and Valley of Mexico Velocity Model

Clay/low velocity deposits thickness



Vs (m/s) at depth=15m



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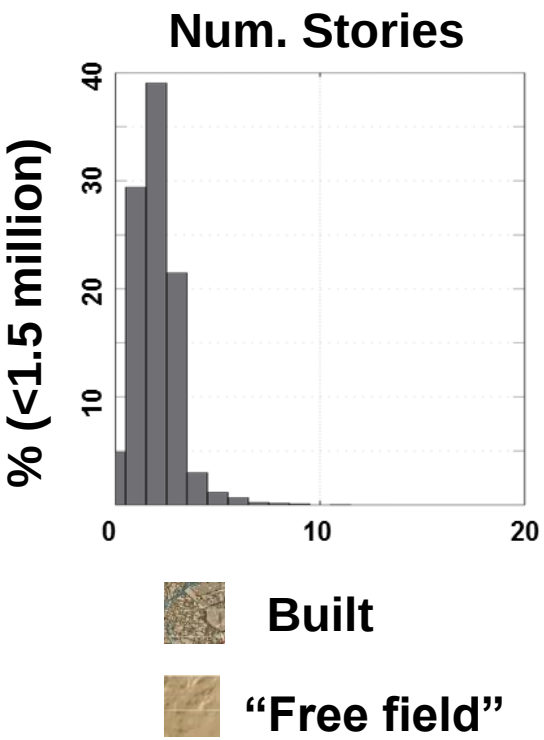
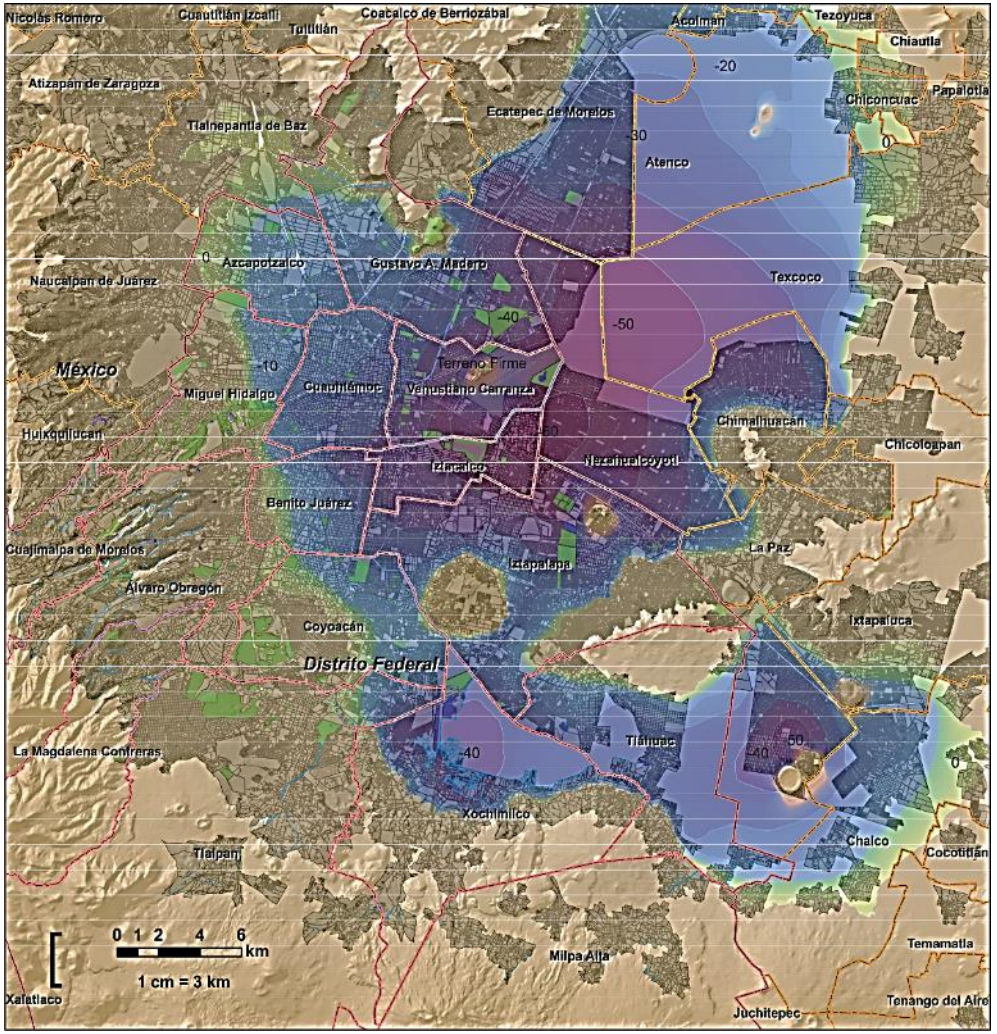
Mexico City Model

Mexico City and Metropolitan Area Building Inventory

Information Available:

- Building inventory
  - Property polygons (city)
  - Property's maximum number of stories
- LIDAR (5m resolution)





Cool color levels depict clay/low Vs thickness

Mexico City Model

Processing Building Inventory and LIDAR

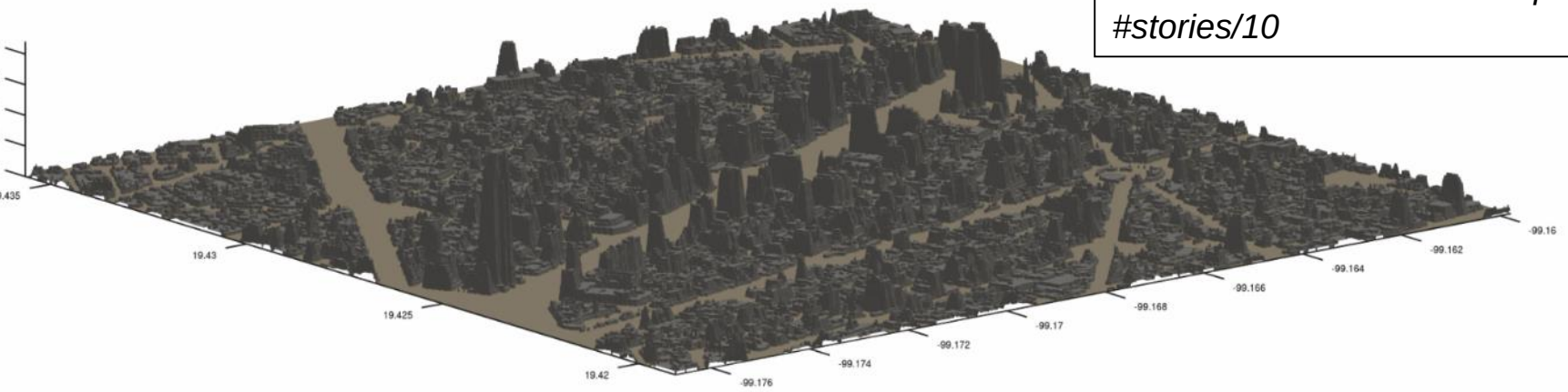
Inventory

- *1 Bit discretization in a regular grid (5m resolution)*
- *Estimate maximum height using # stories*
- *Cross information with LIDAR (remove areas non built areas per property)*

LIDAR

- *Re-discretization in a regular grid (5m)*
- *Apply filters to identify 0 height*
- *Cross information with inventory and apply filters to remove spurious data.*

Vs is assigned assuming that each building behaves like a shear beam and the fundamental period is #stories/10

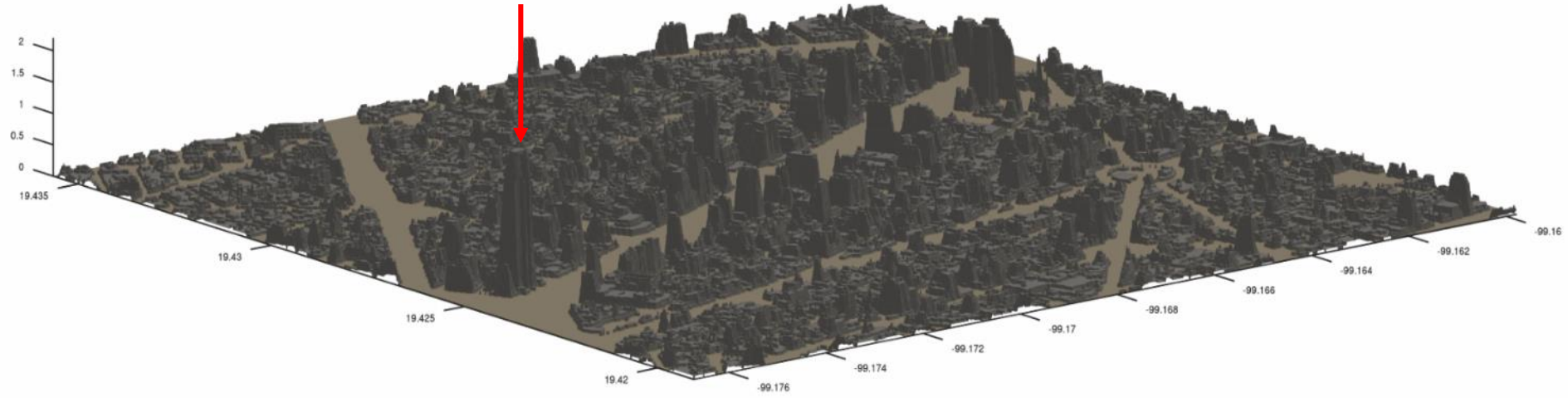


Mexico City Model

Processing Building Inventory and LIDAR

Vs is assigned assuming that each building behaves like a shear beam and the fundamental period is #stories/10

Tallest building (225m)

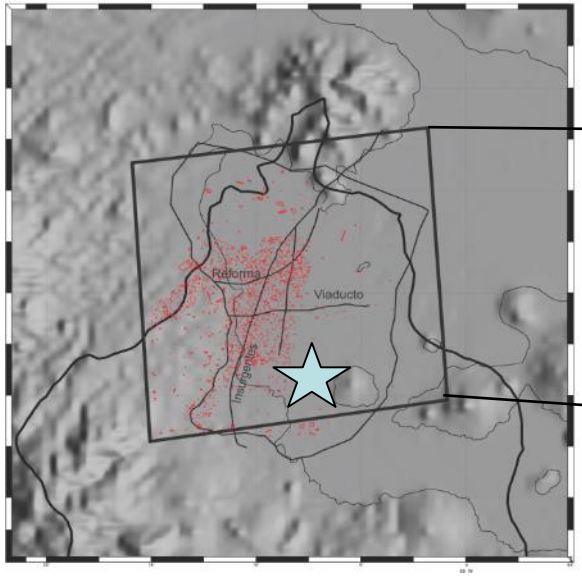


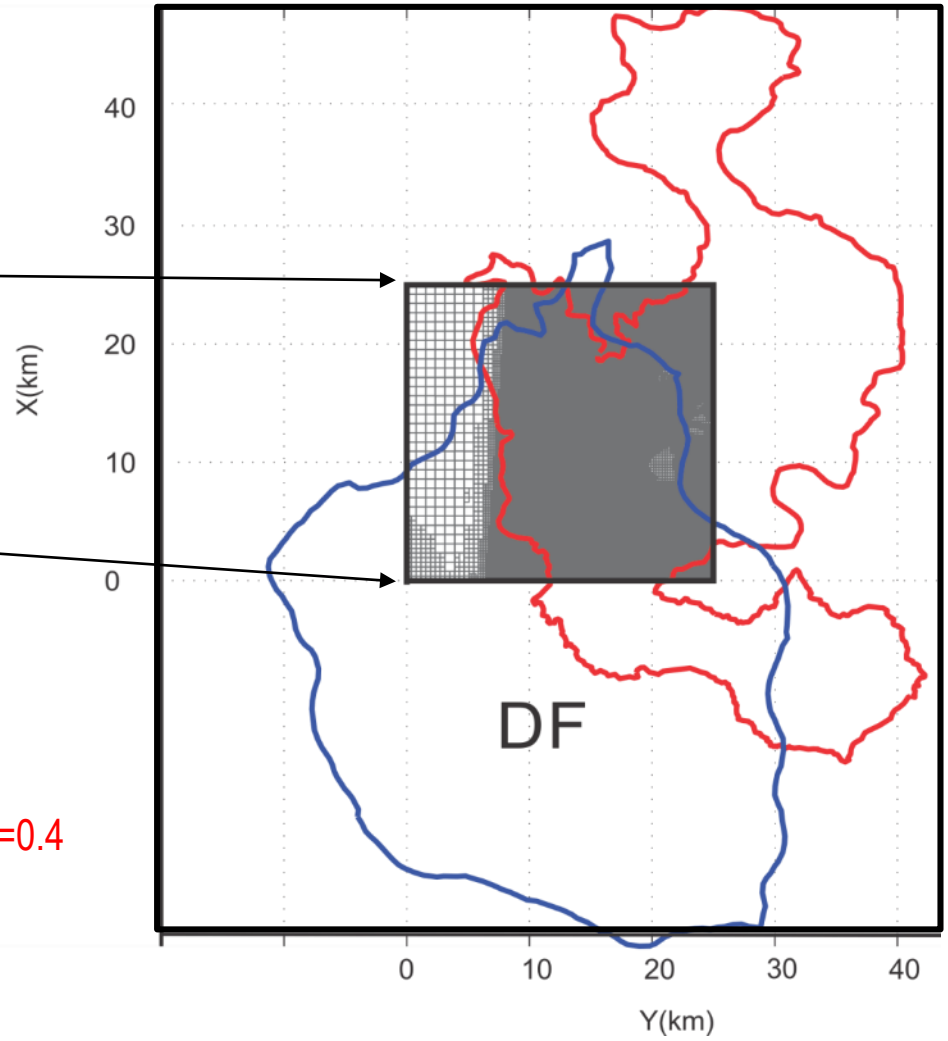
Outline

- Introduction
- City-Soil Interaction
  - Central Mexico and Valley of Mexico Velocity Model
  - Mexico City Model
  - Simulations and Results
- Conclusions

Simulations and Results

Schematic mesh
(True mesh ~9.2 millions elements)



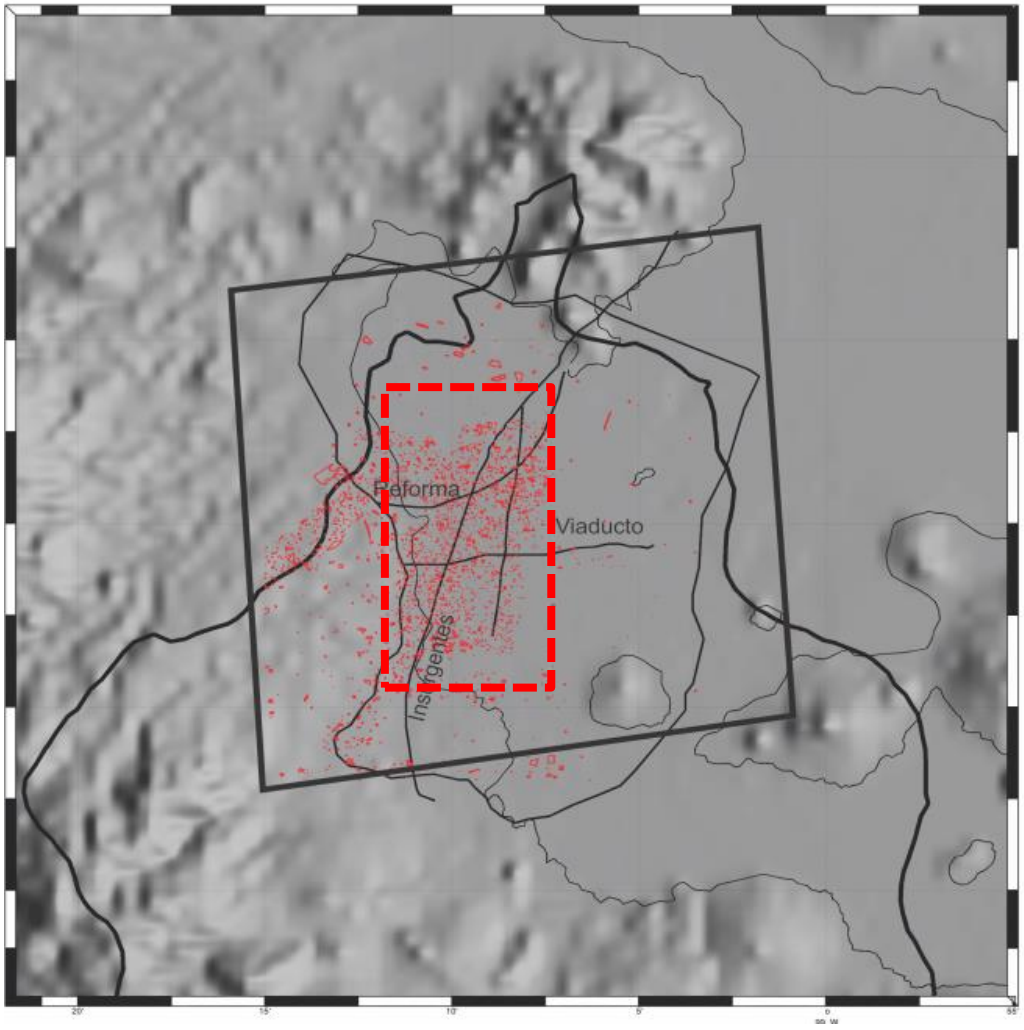


Preliminary Simulation

- Minimum Shear Wave 50 m/s, max f=0.4 Hz , 8-25 ppwl
- Minimum elment size ~10 m .
- Earthquake 10 km deep

Simulations and Results

Peak Ground Velocity ("free surface")



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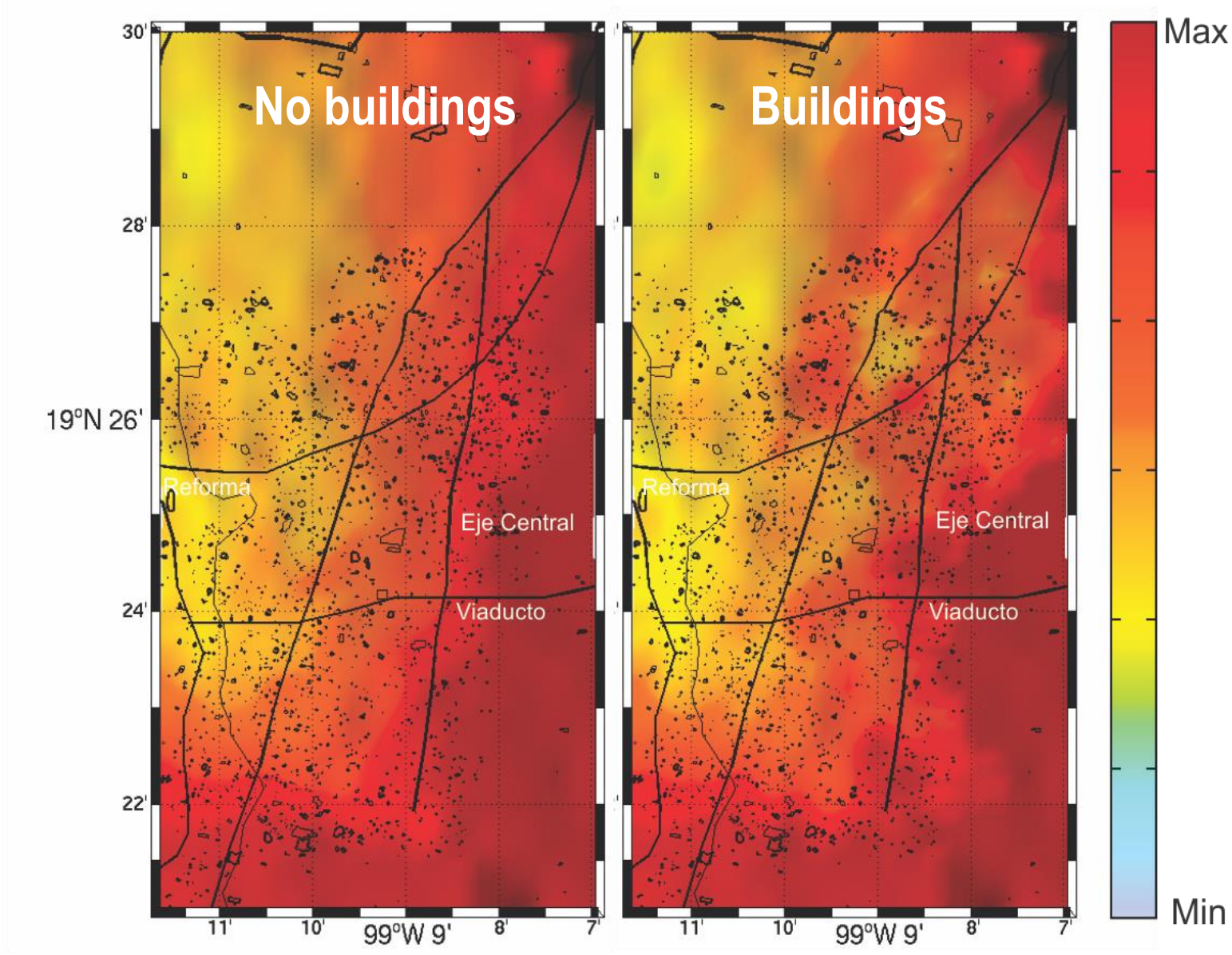
Simulations and Results

Peak Ground Velocity ("free surface")



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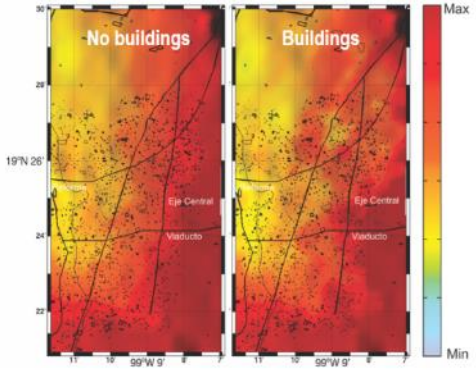
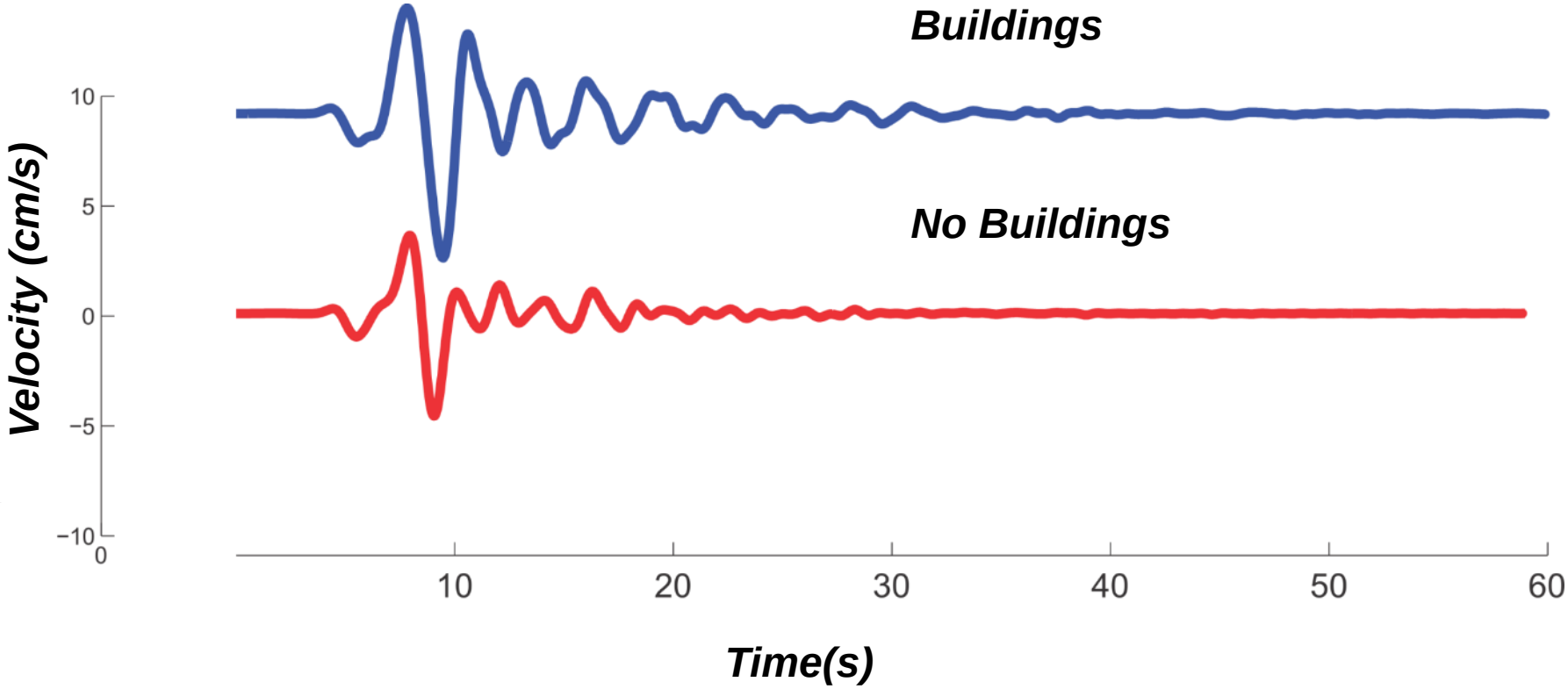
Simulations and Results





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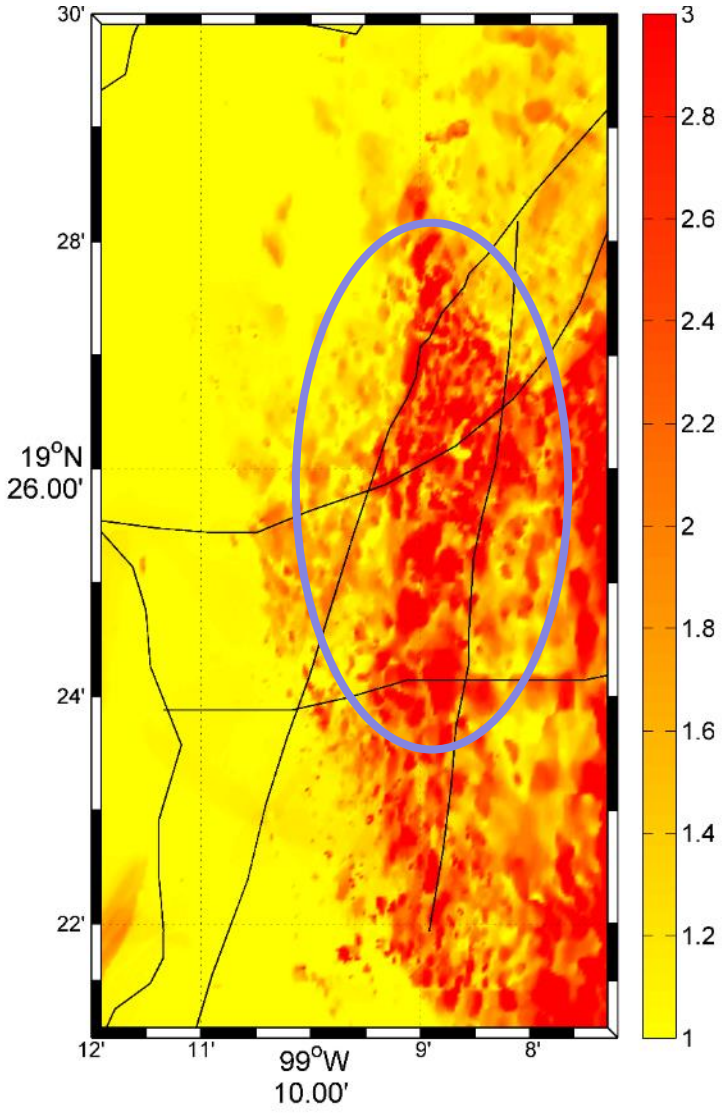
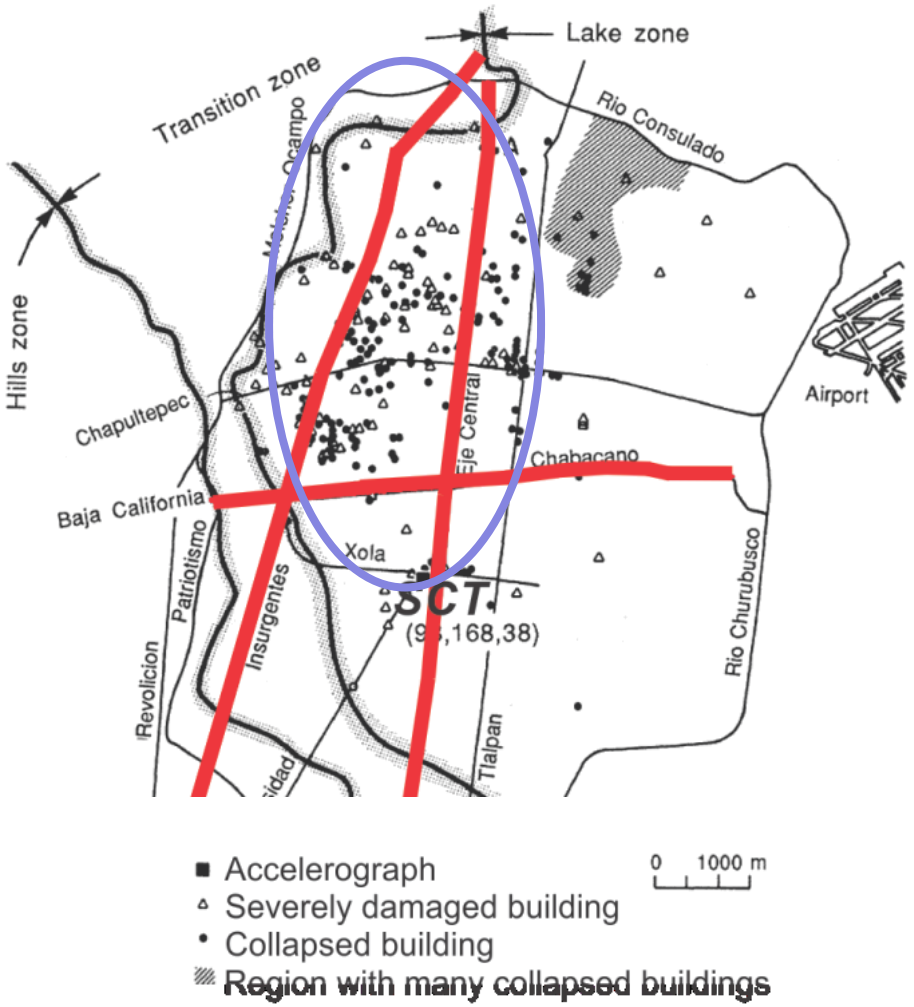
Simulations and Results



Duration Buildings / No building ("free surface")



Duration=time to reach from 0.05 to 0.9 the acceleration energy

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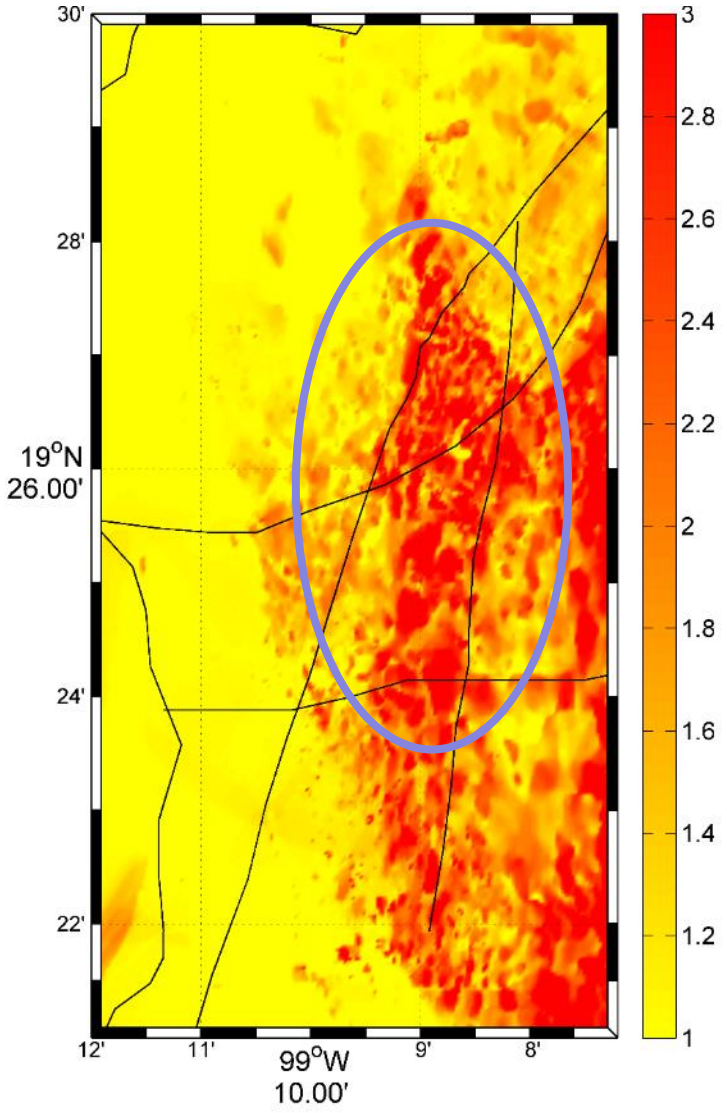
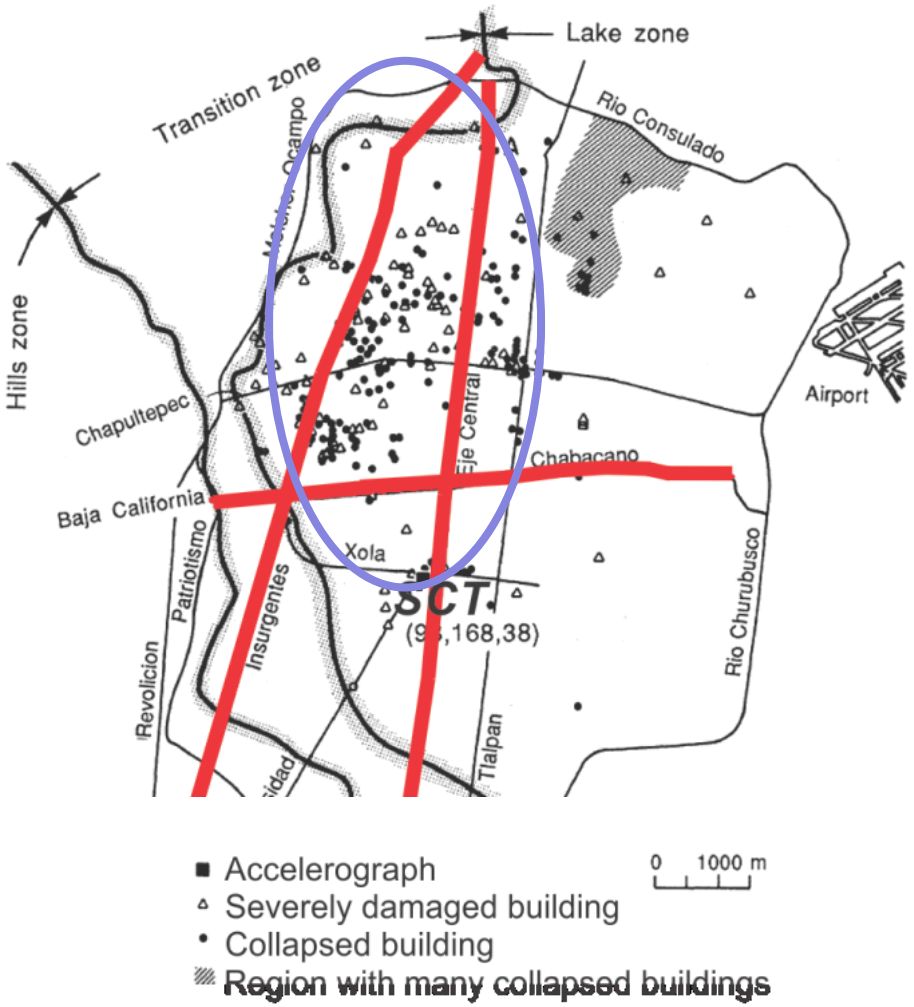
Simulations and Results



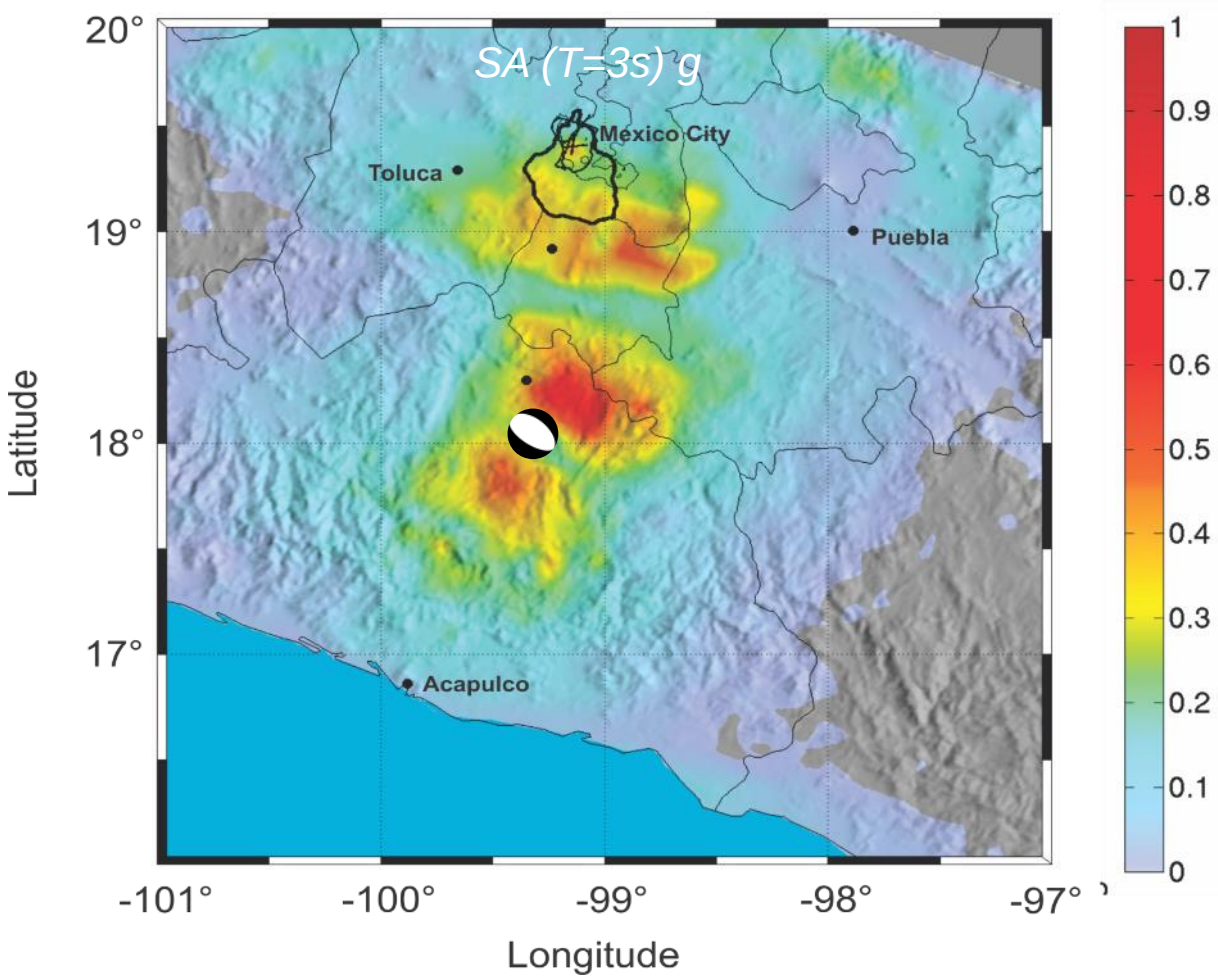
Duration Buildings / No building ("free surface")



Duration=time to reach from 0.05 to 0.9 the acceleration energy

Simulations and Results

- *Intraslab Earthquake*
- *(regional effect minimized)*
- *June 16th Mw=5.9 Huitzuco, Mexico*
- *Maximum Frequency=1Hz*
- *85 seconds simulation*
- *~215 K elements*
- *Minimum element size=2m*



Simulated at DGTIC-UNAM cluster

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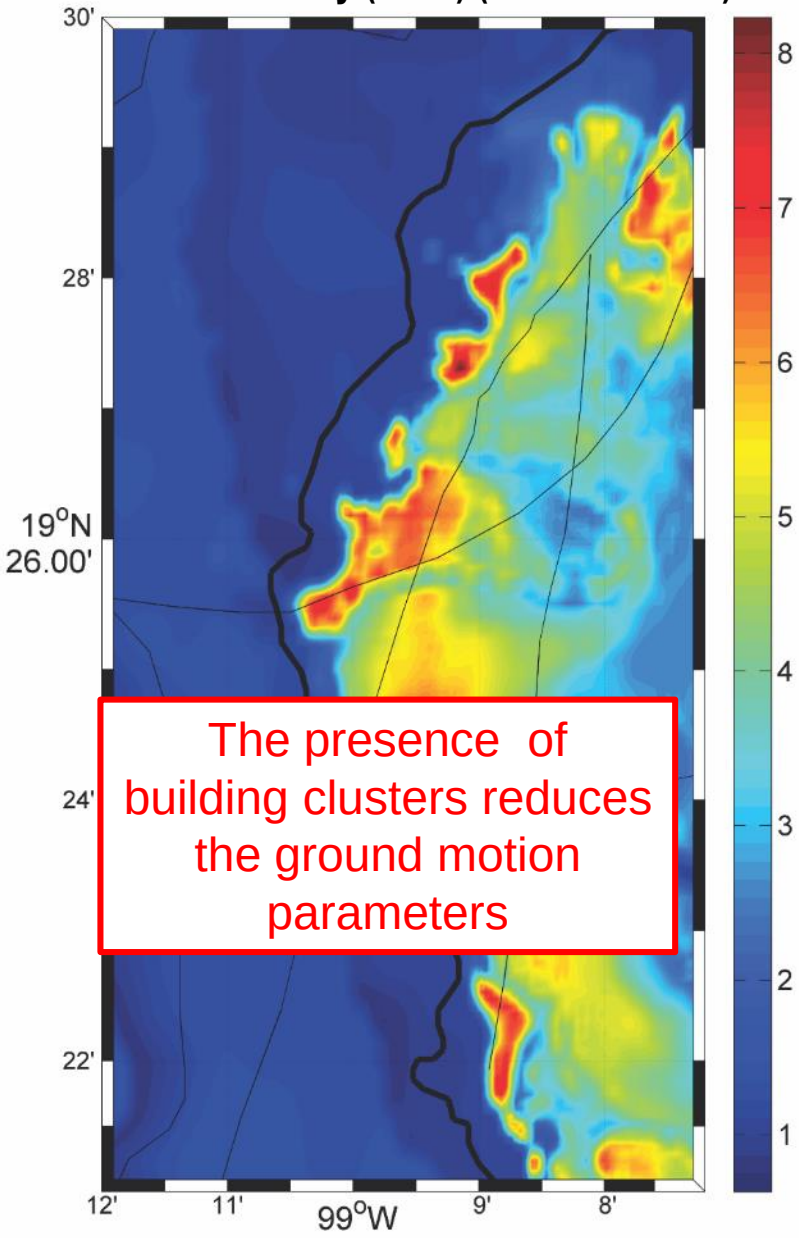
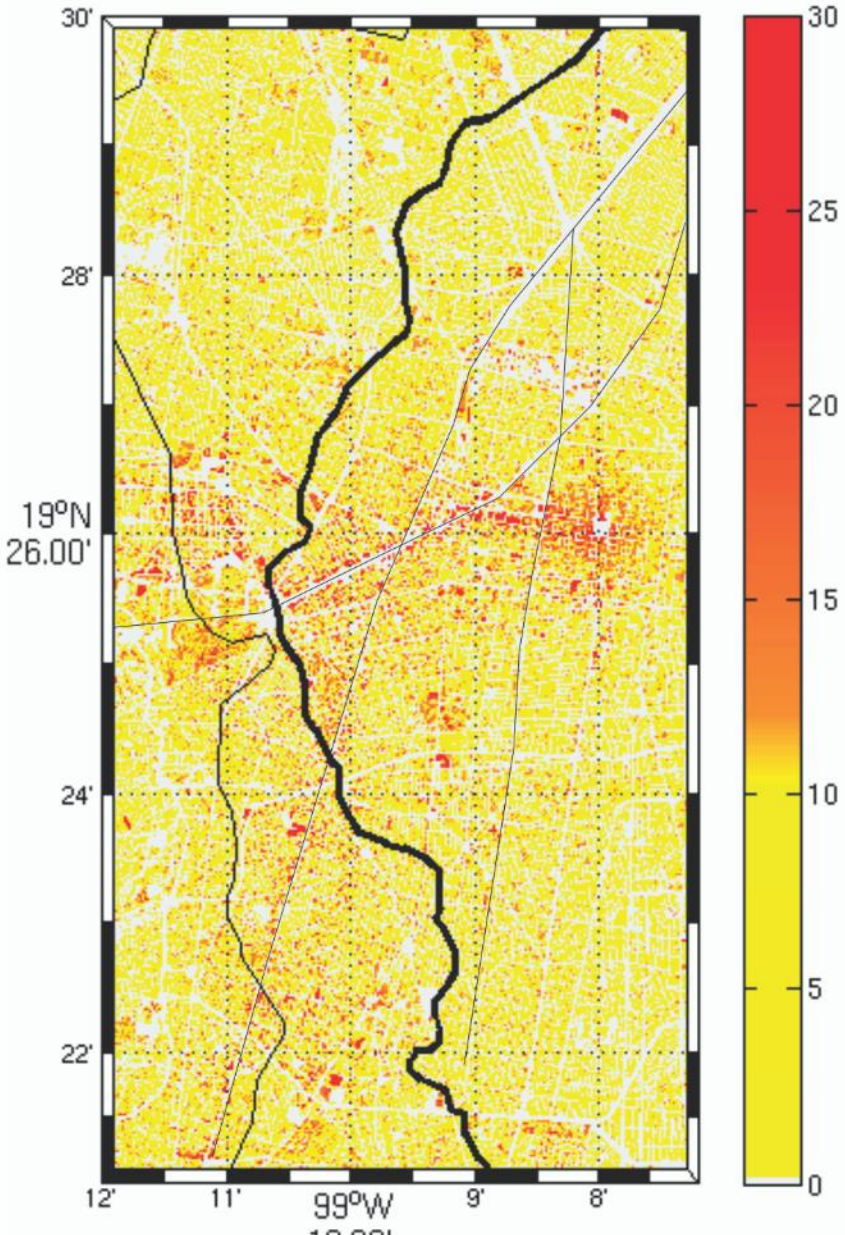
Simulations and Results

Peak Velocity (cm/s) (“free surface”)



The presence of building clusters reduces the ground motion parameters

Building height (m) <30m



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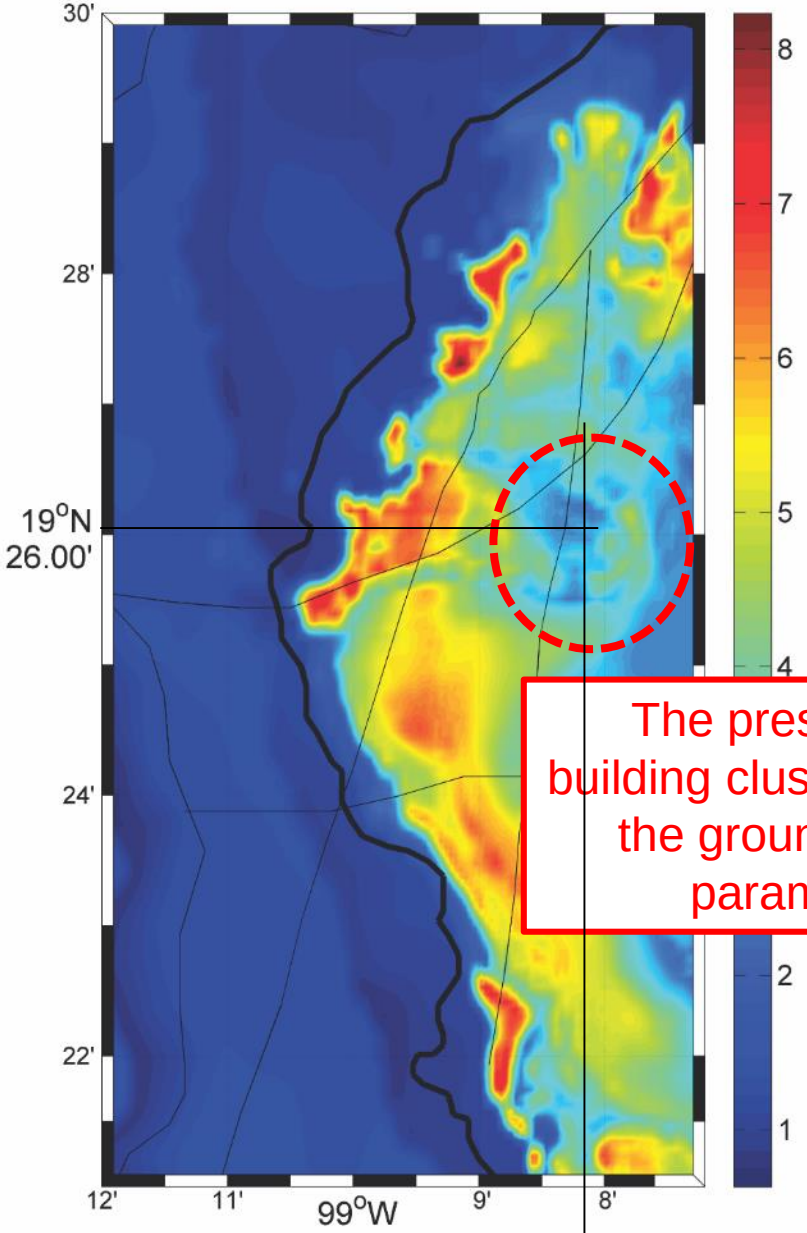
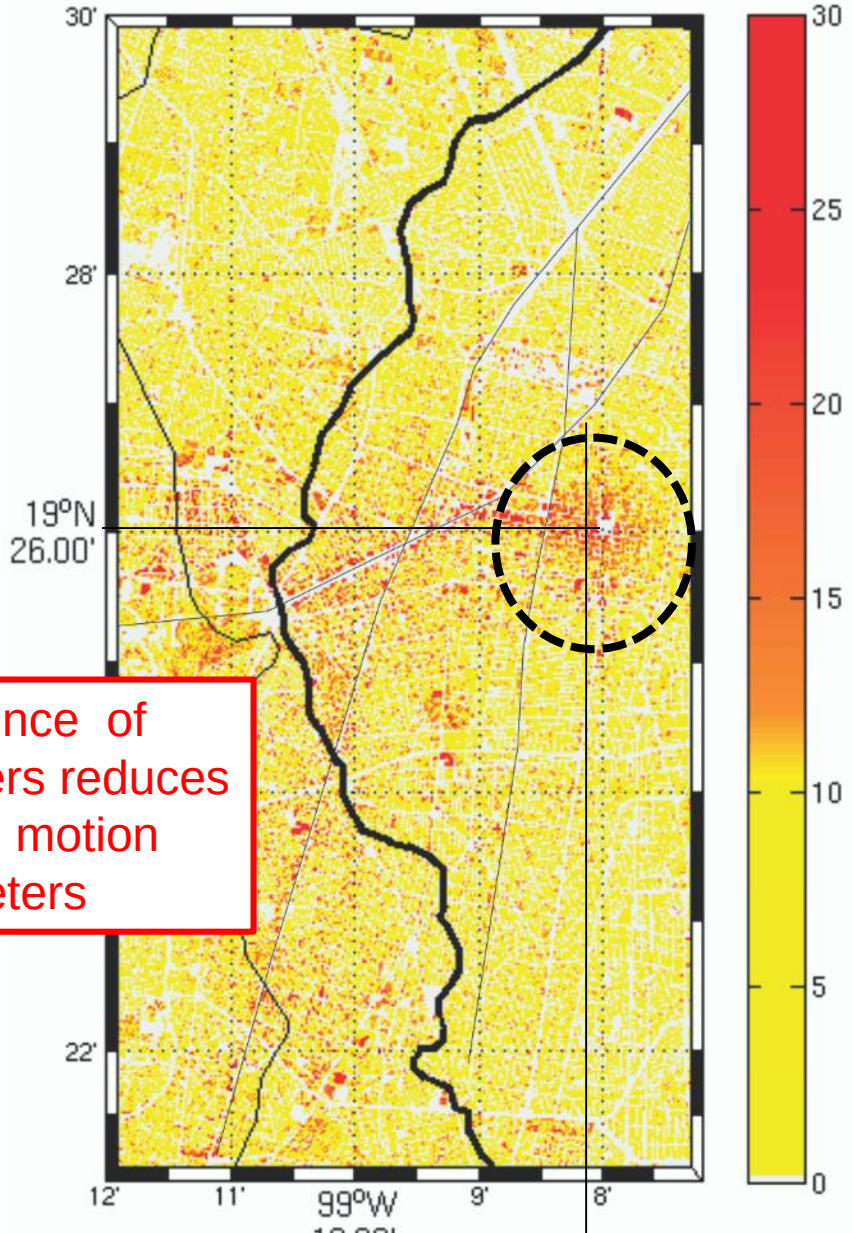
Simulations and Results

Peak Velocity ("free surface")



Building height



The presence of building clusters reduces the ground motion parameters

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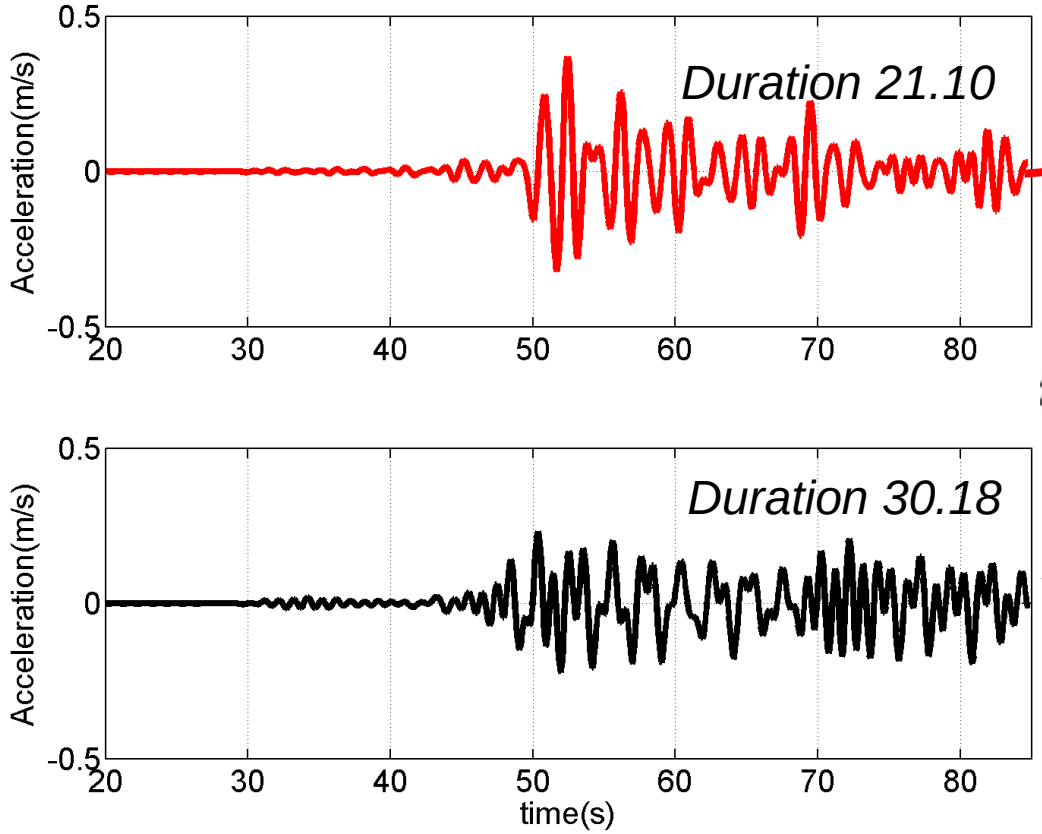
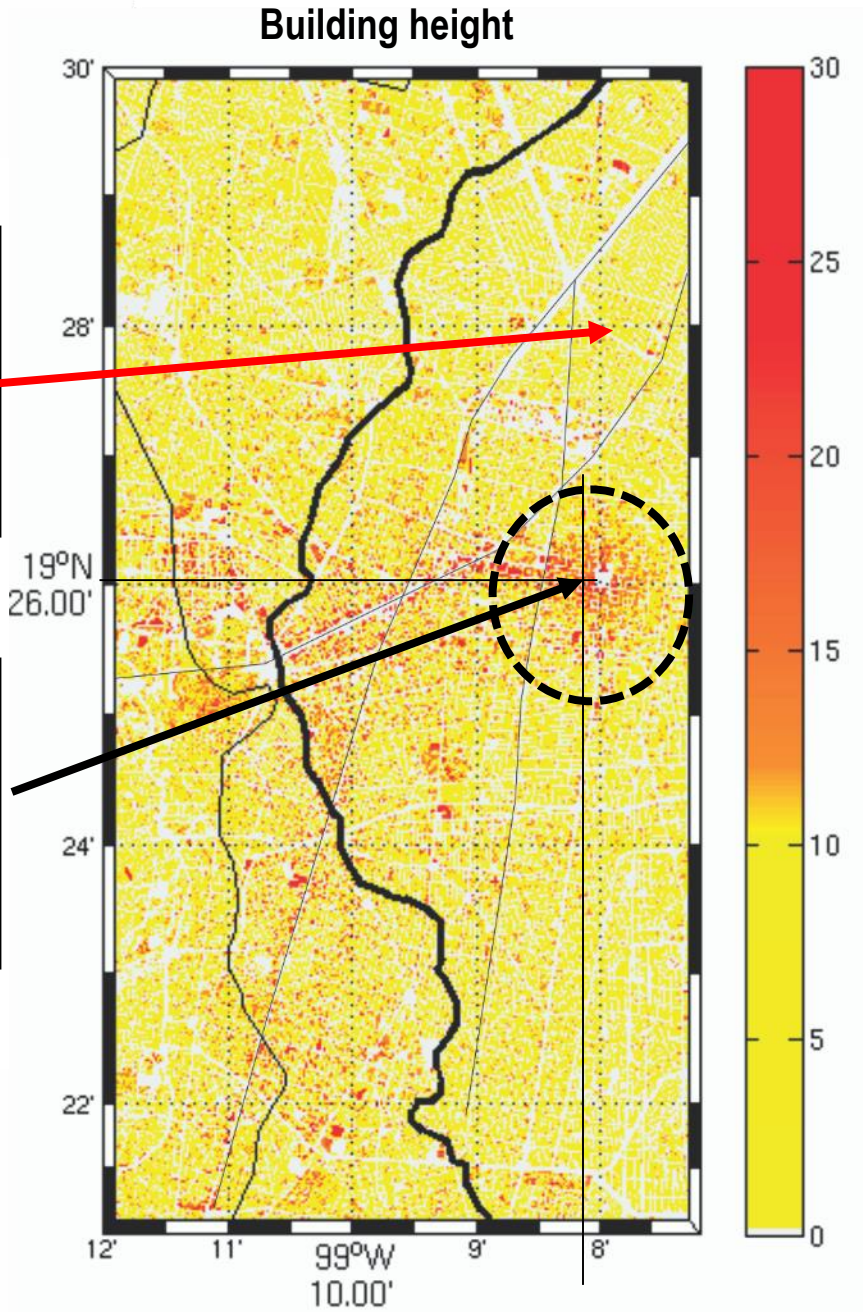
Simulations and Results

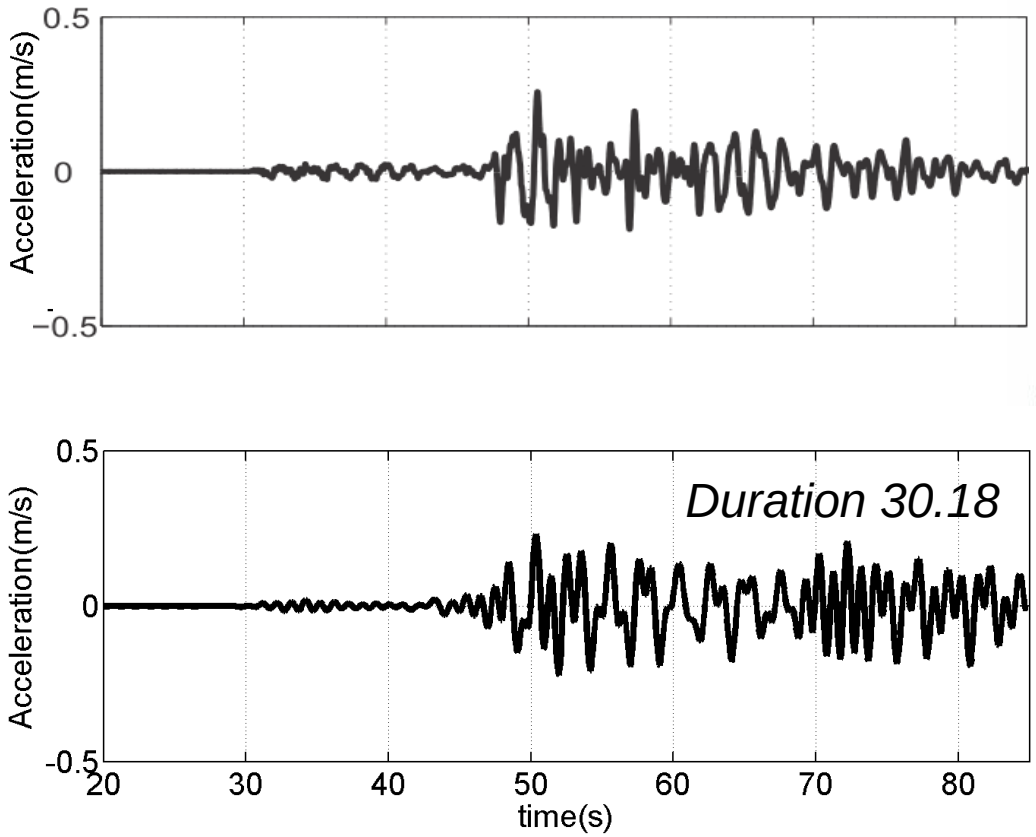


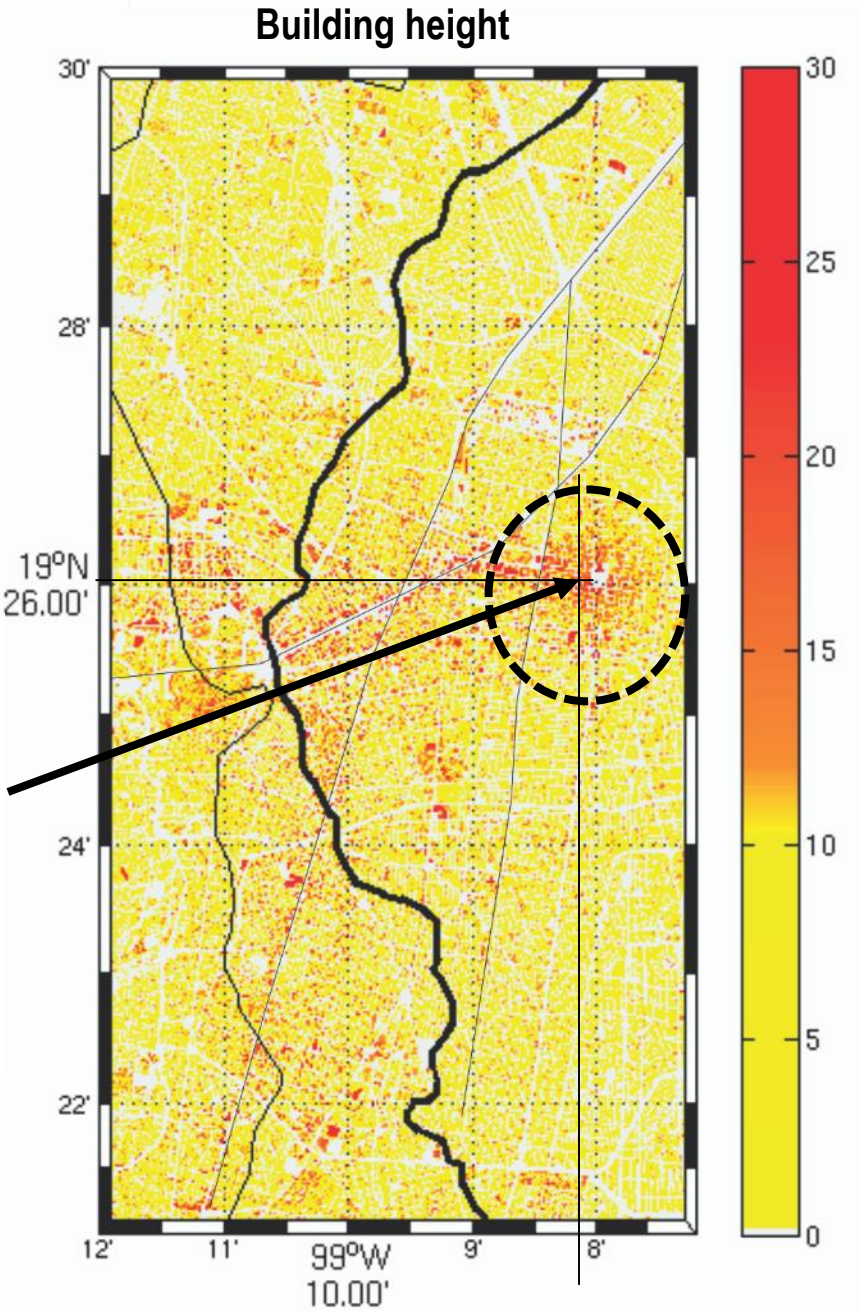


Duration=time to reach from 0.05 to 0.9 the acceleration energy

Simulations and Results

DATA RACM(CIRES)
Station GA62 (filtered)





Duration=time to reach from 0.05 to 0.9 the acceleration energy

Conclusions

- The effect of the build environment on the wave field is important in Mexico City.
- Peak ground motions parameters tend to be lower when building clusters are present
- The buildings are one of the mechanisms that can be responsible for the observed in the ground motion in Mexico City.
- A larger set of simulated earthquakes is required.