Assessment of Seismic Hazard and Risk in Emirate of Abu Dhabi - ADSHRA

3D Simulation of Long-period Seismic Waves in United Arab Emirates from Distant Large Earthquakes

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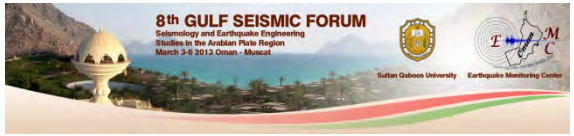
SULTAN QABOOS UNIVERSITY
EARTHQUAKE MONITORING CENTER



8th Gulf Seismic Forum
3-6 March 2013, Muscat, Oman

PROJECT RESOURCES

Contractor

GEOSCOPE

KINEMETRICS

REC

GRM İletişim ve Bilişim

ZETAŞ ZEMİN TEKNOLOJİSİ A.Ş.

Consultant

GECO

IZIIS

Objective

- Construct a 3D numerical seismic velocity model for the region and use it in the 3D simulation of seismic wave propagation and waveforms.

- Simulated waveforms are intended for use in performance and seismic vulnerability assessment of tall buildings and other long period structures in the Emirate of Abu Dhabi.

Task Activities

- Tectonic model and scenario earthquakes
- 3D regional velocity model
- Wave propagation modeling for scenario earthquakes
- Waveforms for Scenario Earthquakes
- GIS tool for visualization of the 3D velocity model and for selection of grid-based simulated
- waveforms

Numerical Method

- Finite Difference
- Suitable tool to simulate wave propagation in heterogeneous media
- Madariaga et al. (1998) extended the fourth-order staggered-grid finite-difference method to study faulting in three dimensions.
- Code FD3D

Velocity Structure

Should be based on:

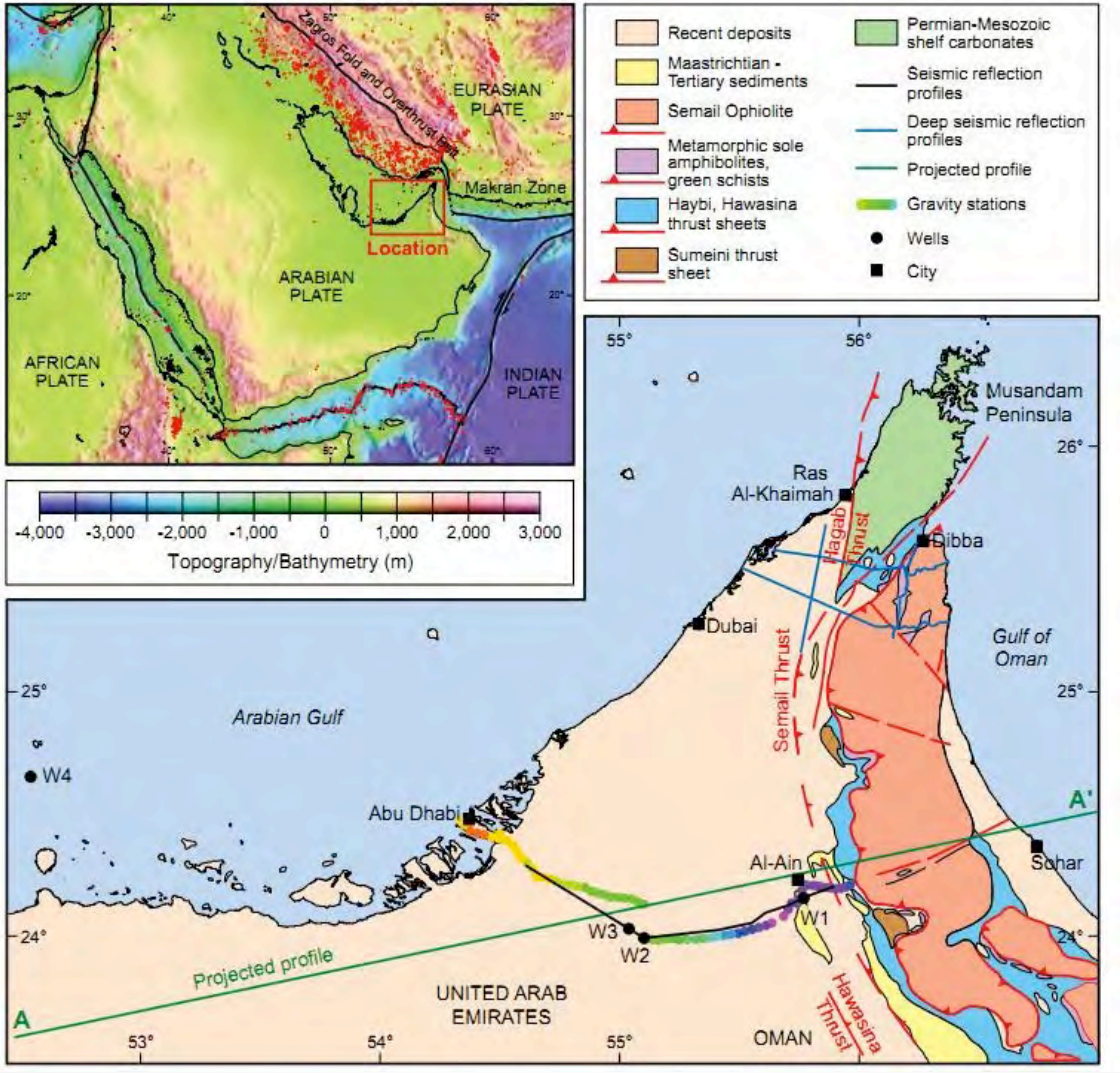
- Identification and interpretation of complex geometry and characteristics (Vp and Vs velocities, and densities) of sedimentary basin models in the region
- Definition of the crustal model representing the rocks outside of the rule-based basin models and the depth of Moho defined based on literature survey, already published results and/or determined from receiver functions of tele-seismic events recorded at broadband stations.

Development of the 3D Velocity Model

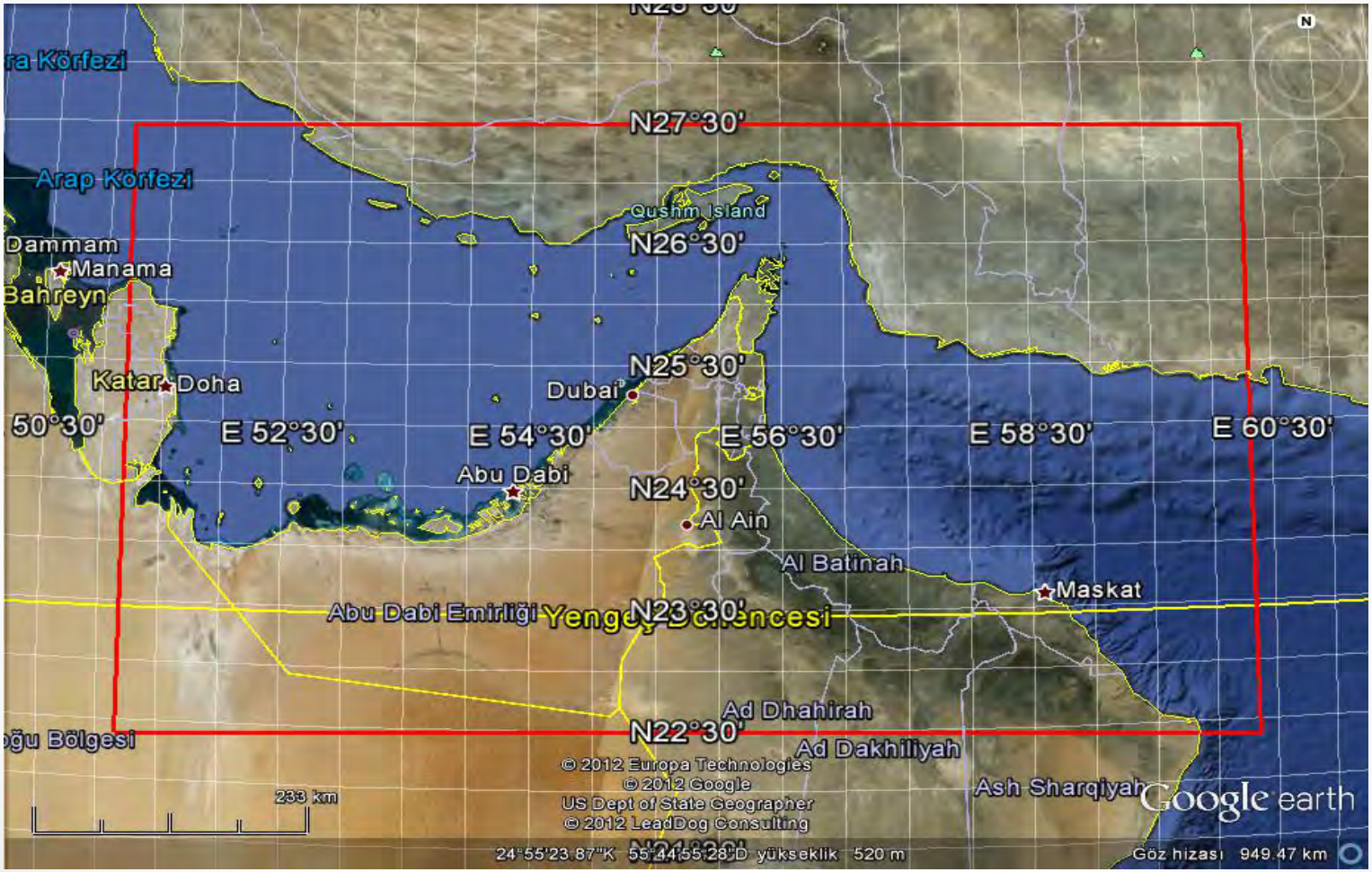
- Needs to reflect the characteristics of the geologic formations in the United Arab Emirates, in regions in the immediate vicinity of the Emirates, as well as in the Makran and Zagros regions.

- It has to be based on the information about the 3D depth variation of the Moho, of the continental basement and of the overlying sediments.

Geological map of the United Arab Emirates from Ali and Watts (2009)

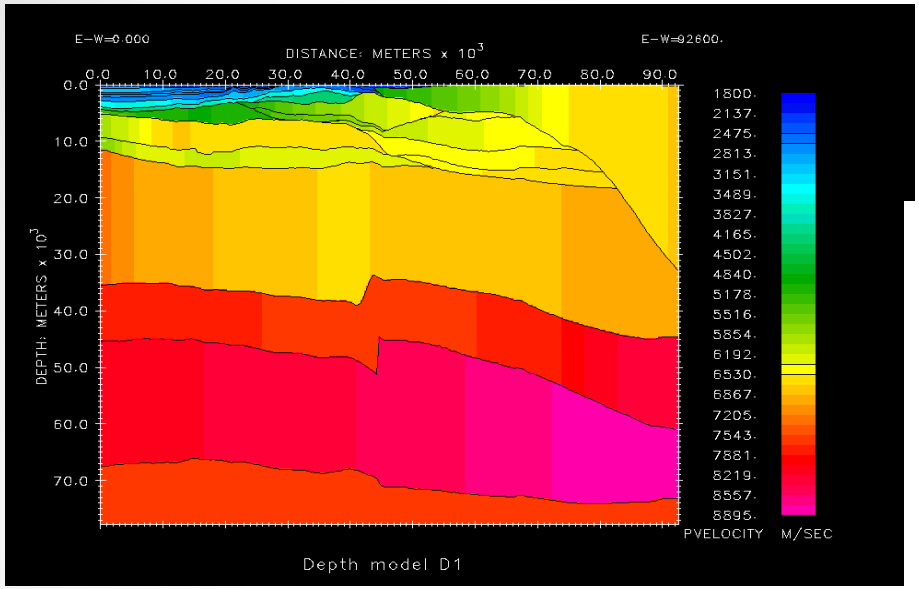


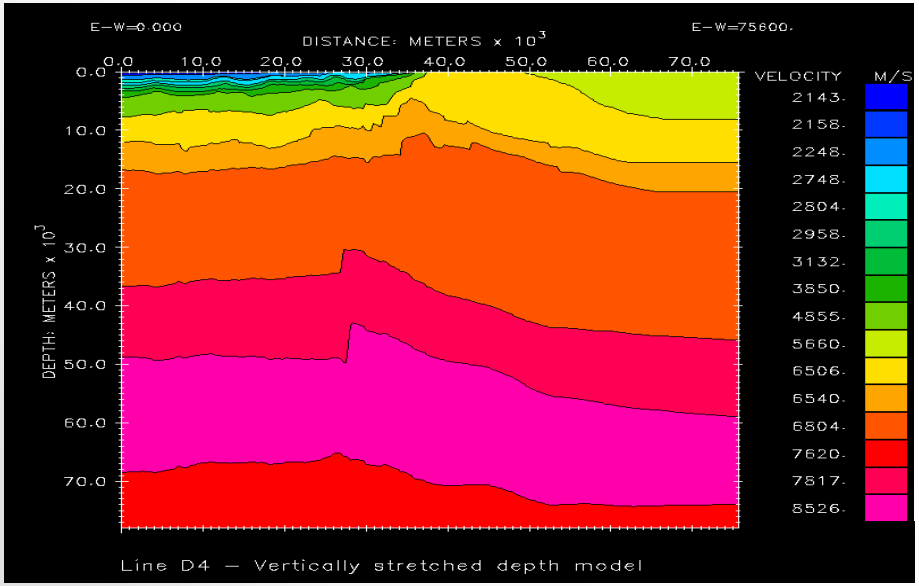
Planar extent of the region modeled



It extends for 924 km in the EW direction, 560 km in the NS direction and 47 km down

Profiles available for modelling





Depth profile of line D1 (top) and line D4 (bottom), after WesternGeco, 2005

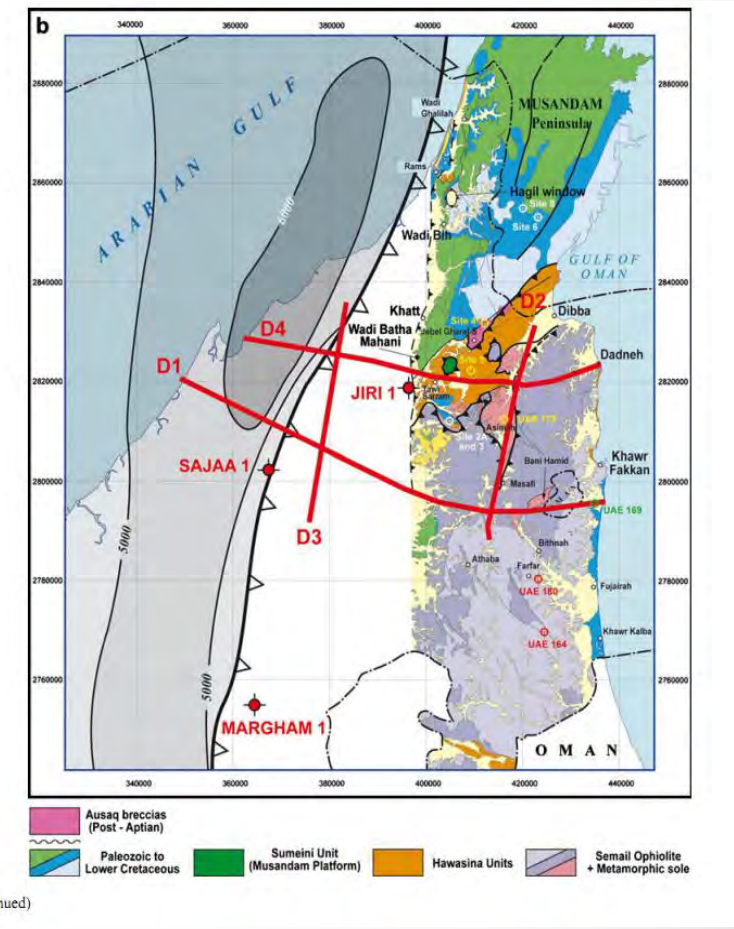
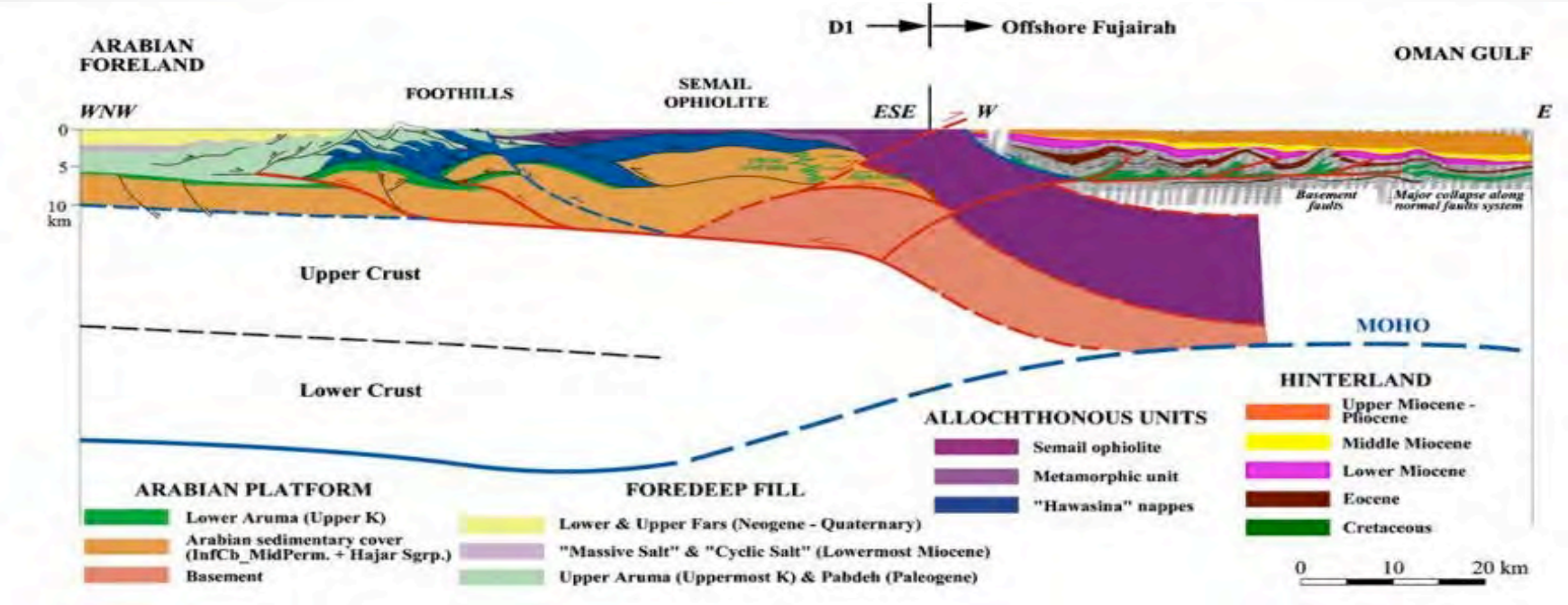


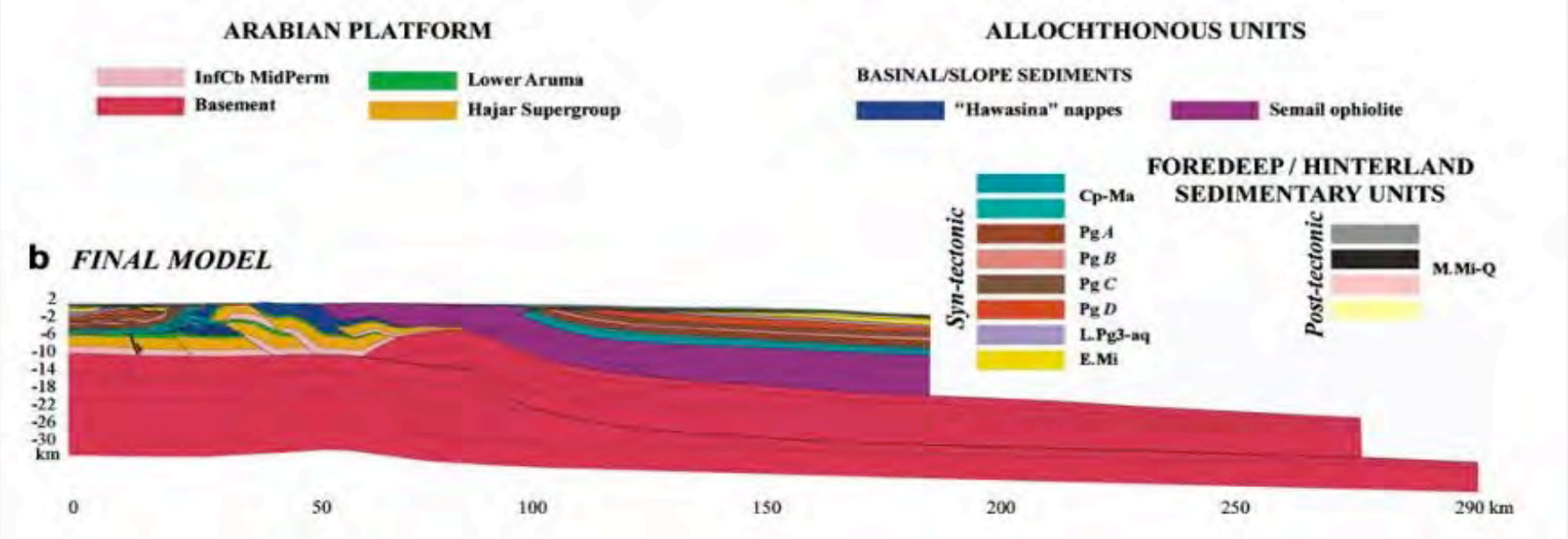
Fig. 1 (continued)

Profiles available for modelling



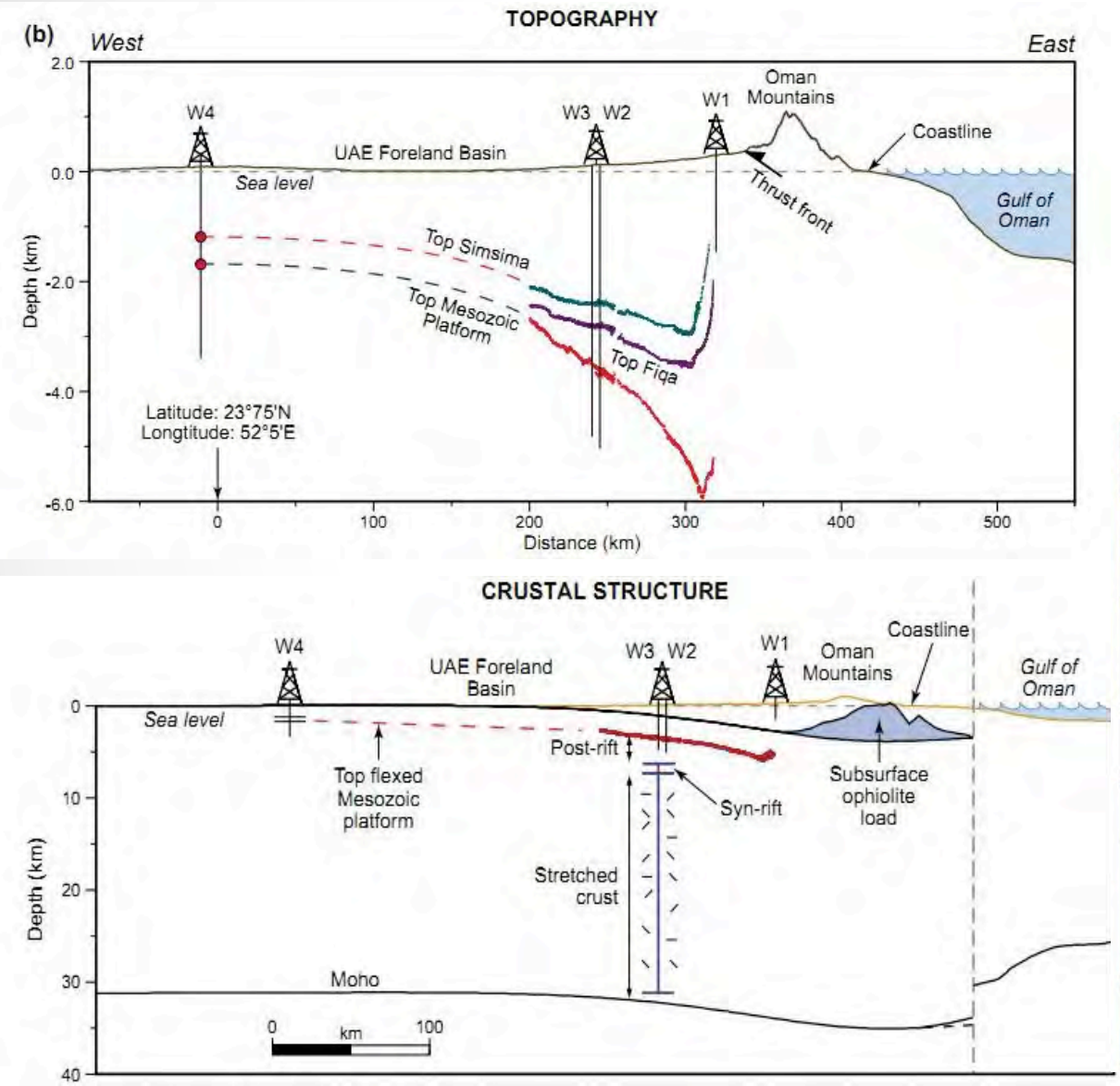
Crustal structure along profile D1, extending into the Oman Gulf, after Tarpoanca et al(2010)

Profiles available for modelling

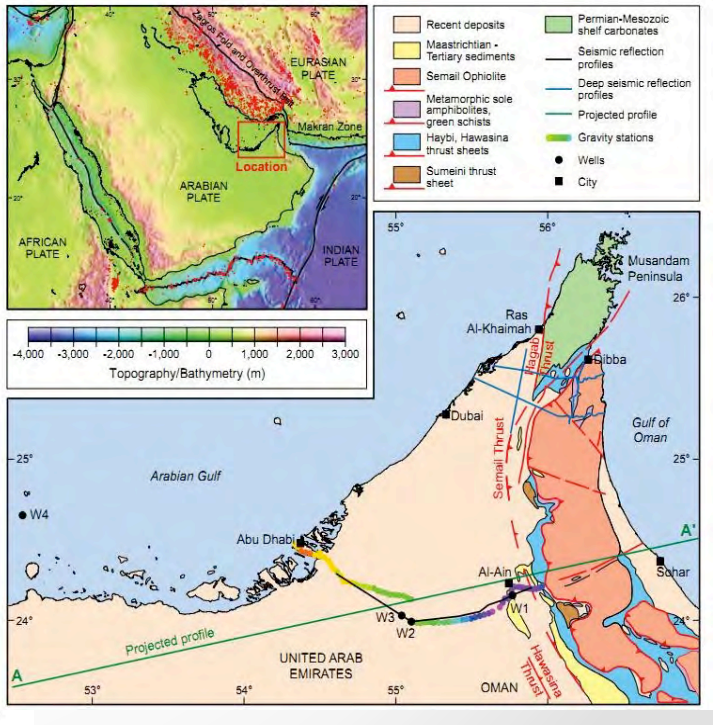


Crustal structure along profile D4, extending into the Oman Gulf, after Tarpoanca et al (2010)

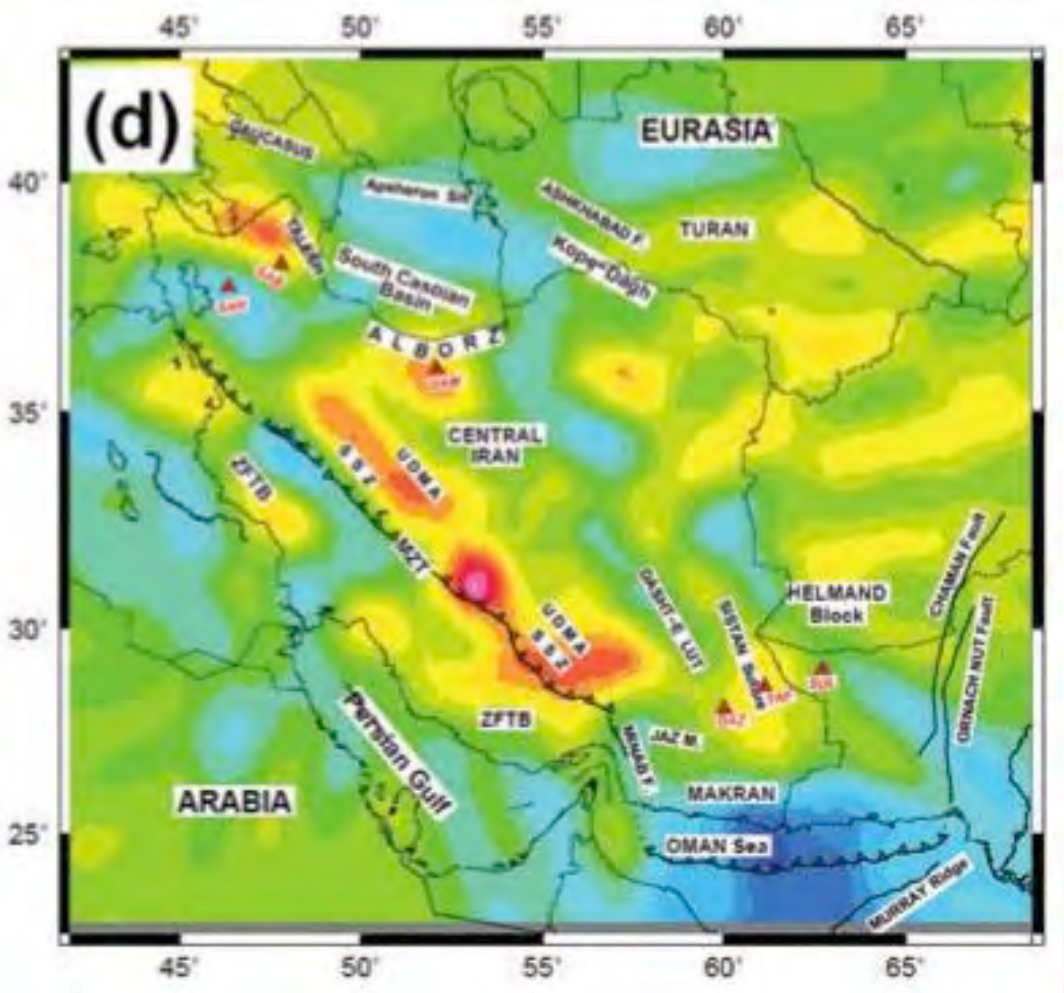
Profiles available for modelling



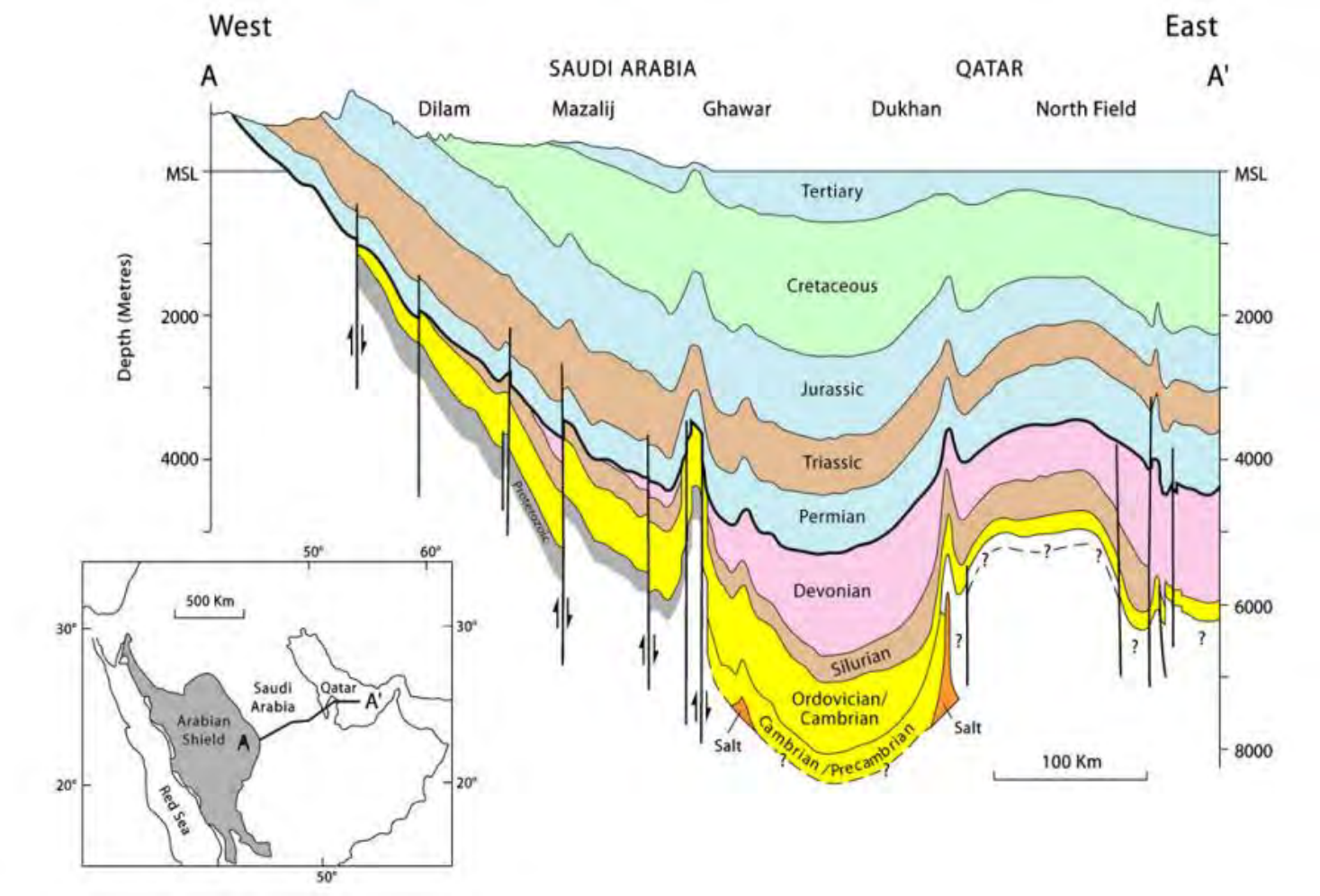
Shallow profile (top) and crustal structure down to 40km (bottom) along profile AA'. (Ali and Watts, 2009).



Moho map across the Iranian plateau after Manaman et al, 2010

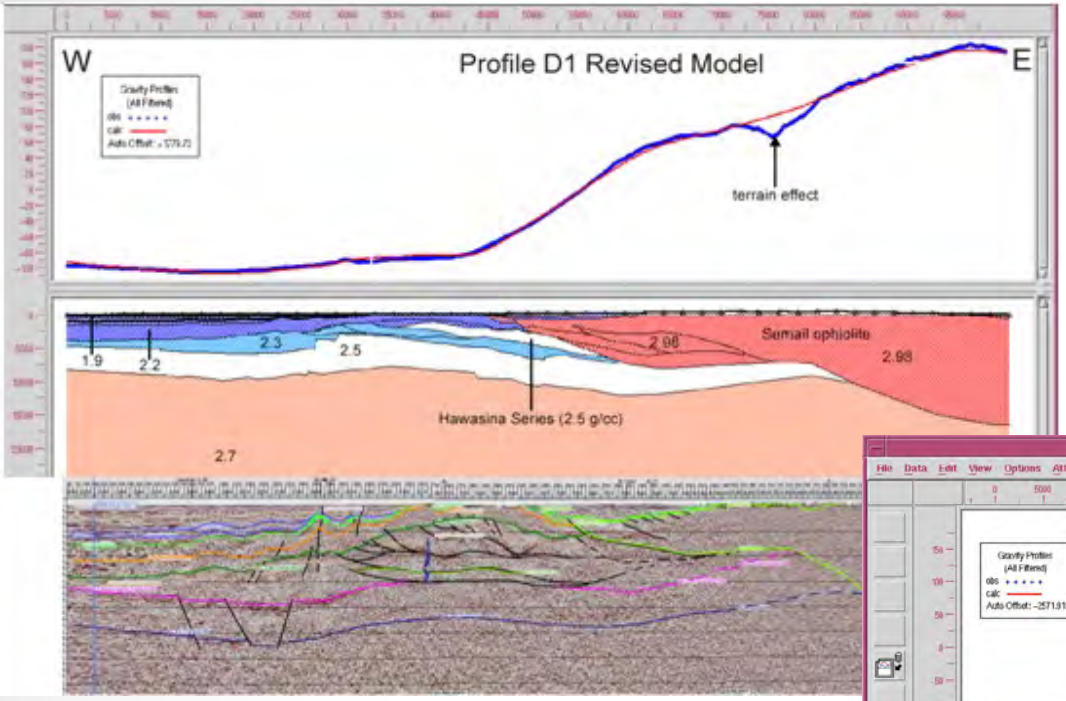


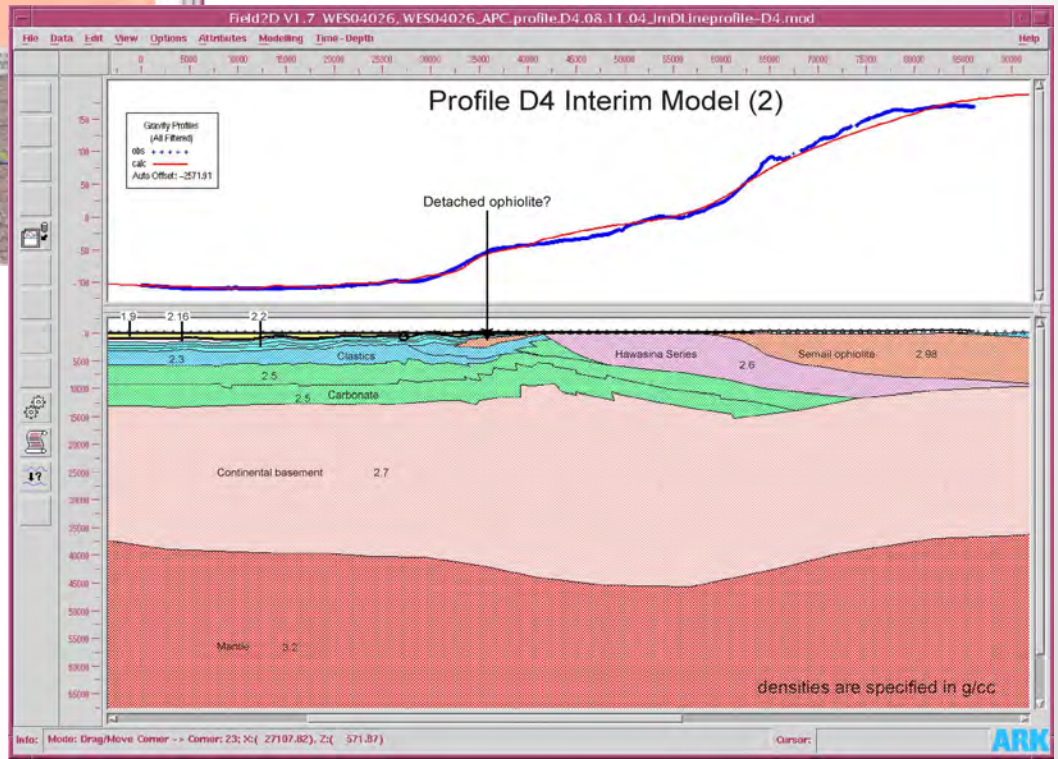
Cross section covering the Arabian platform, Qatar and the Arabian Gulf (Glennie, 2010)



- The folding between Qatar and end of the section on the right was helpful in constraining the western elongation of section D4.

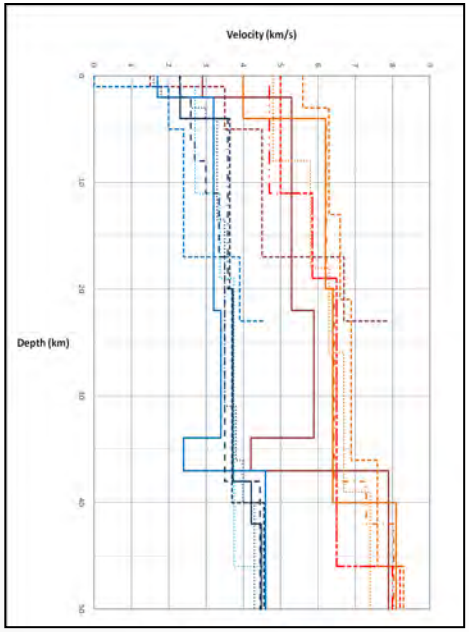
Density profile of section D1 (top) and D4 (bottom) WesternGeco (2005)



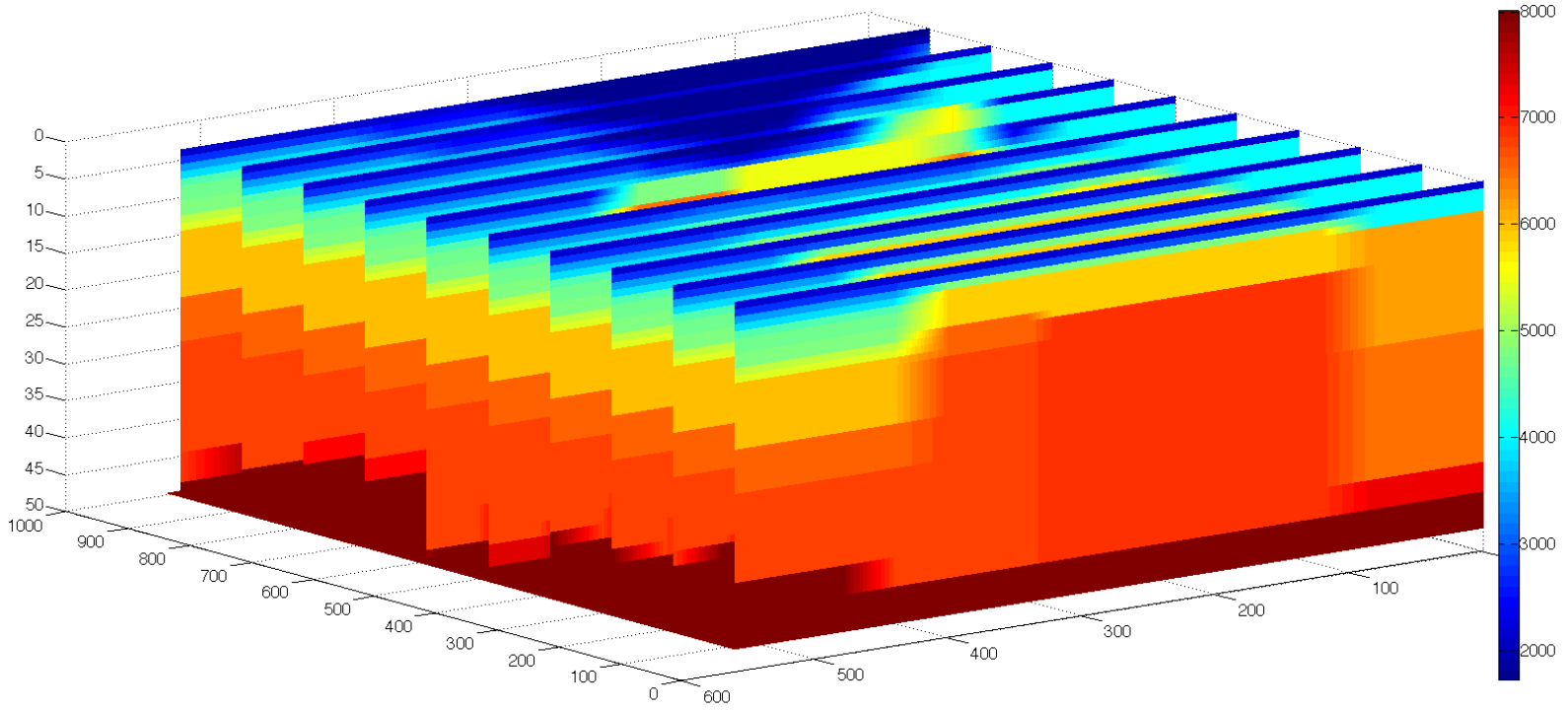


1D velocity model adopted for 3D wave propagation modeling (Adams at al., 2009)

Depth (km)	Vp (km/s)	Vs (km/s)	Density (t/m3)
0-4	4	2.31	2.20
4-20	6.22	3.59	2.40
20-38	6.44	3.72	2.70
38-42	7.30	4.21	2.70
42-	8.04	4.48	3.26



3D Vp model

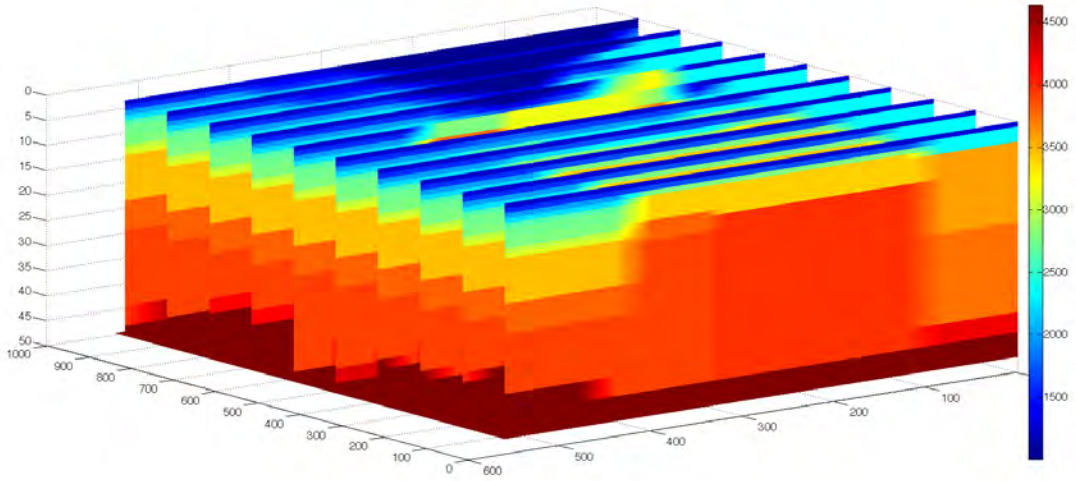


Dimensions 924 km x 560 km x 47 km in the east-west (x), north-south (y) and vertical (z) directions respectively.

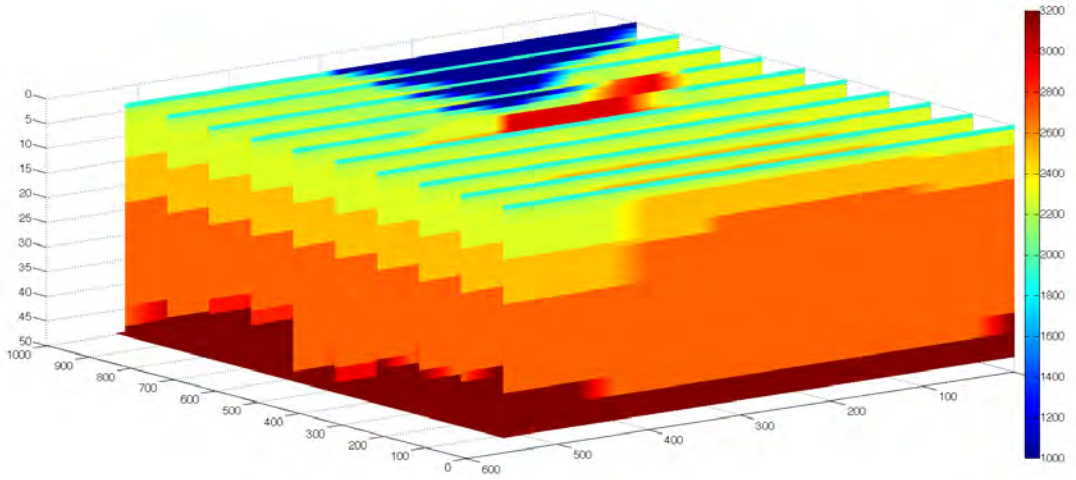
The grid size is 1km in three directions.

It has 24 908 400 elements.

3D Vs model



3D Density model



VALIDATION OF THE 3D VELOCITY STRUCTURE

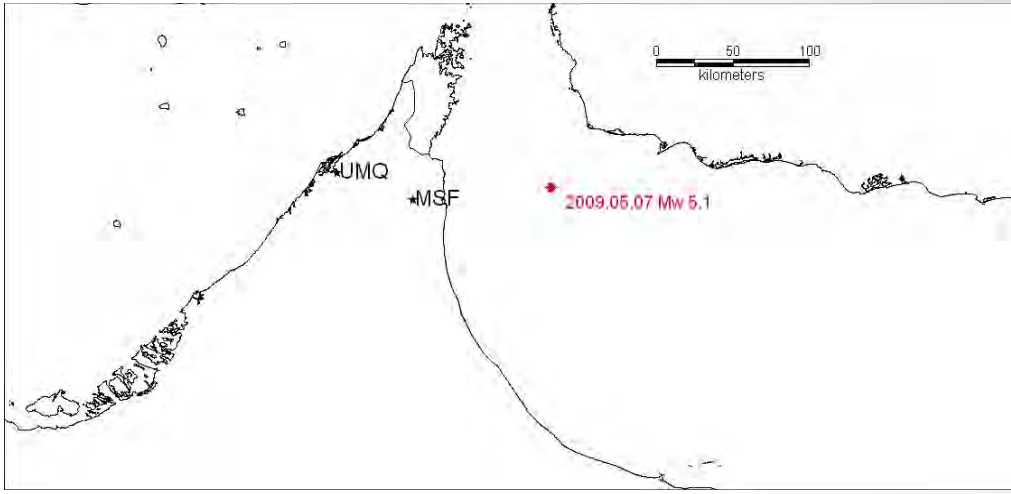
Networks and data used in the validation

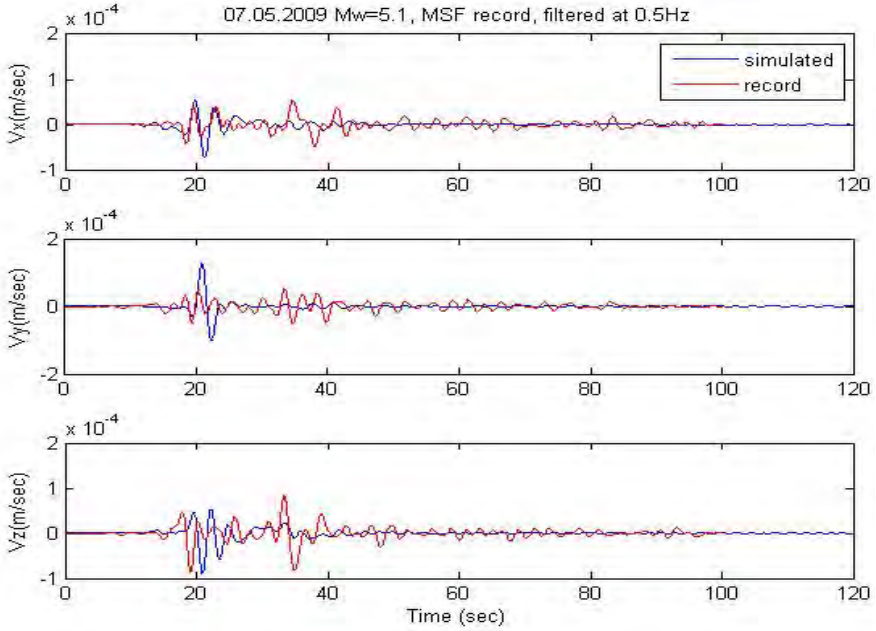
- UOSS station (Global Seismic Network, located at the University of Sharjah)
- DN (Dubai Seismological Network), 4 stations: ASU, FAQ, HAT and NAZ
- NCMS (National Center of Meteorology and Seismology of UAE) network, composed of several stations in UAE.

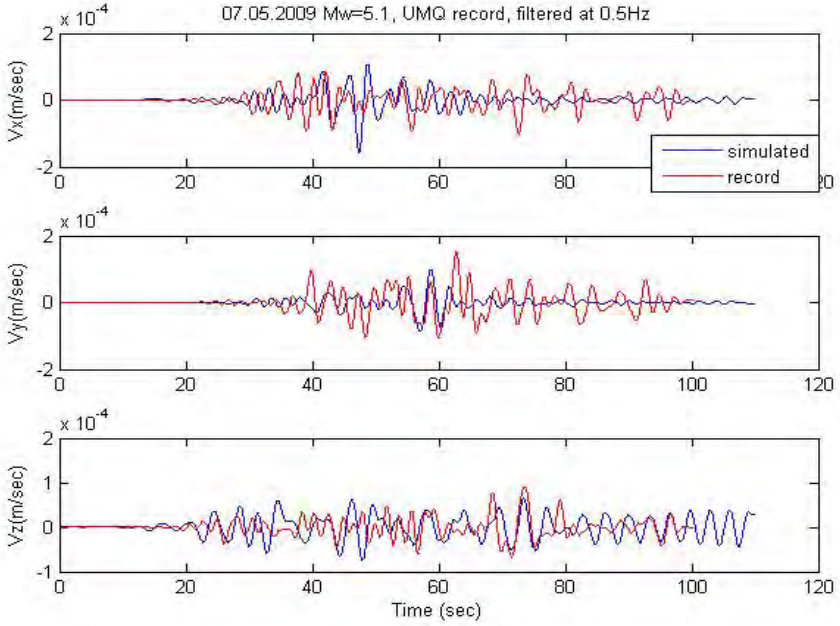
Datasets

- UOSS data
- Local data (events occurred inland in UAE) from DN
- Regional data (events from around UAE) from DN
- NCMS data

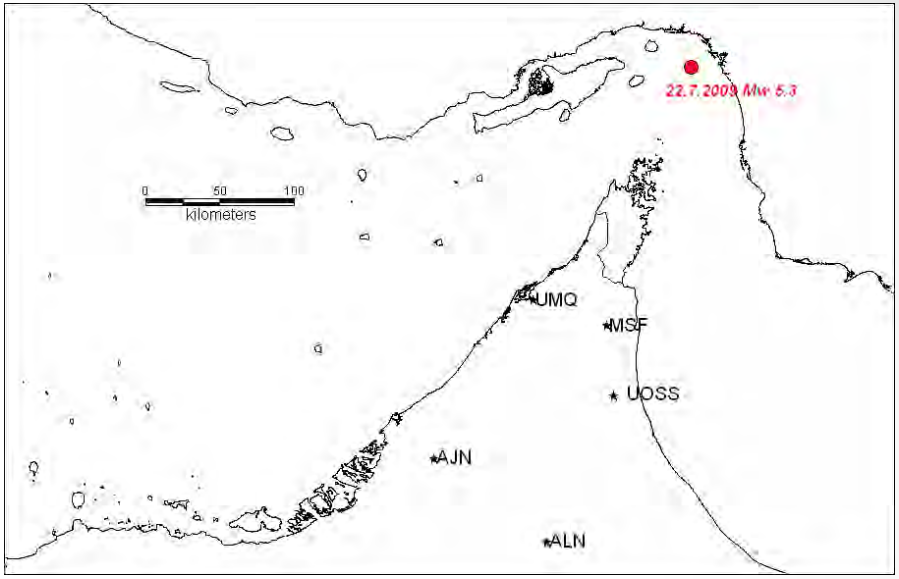
The 07.05.2009 Mw=5.1 event occurred offshore, west of UAE

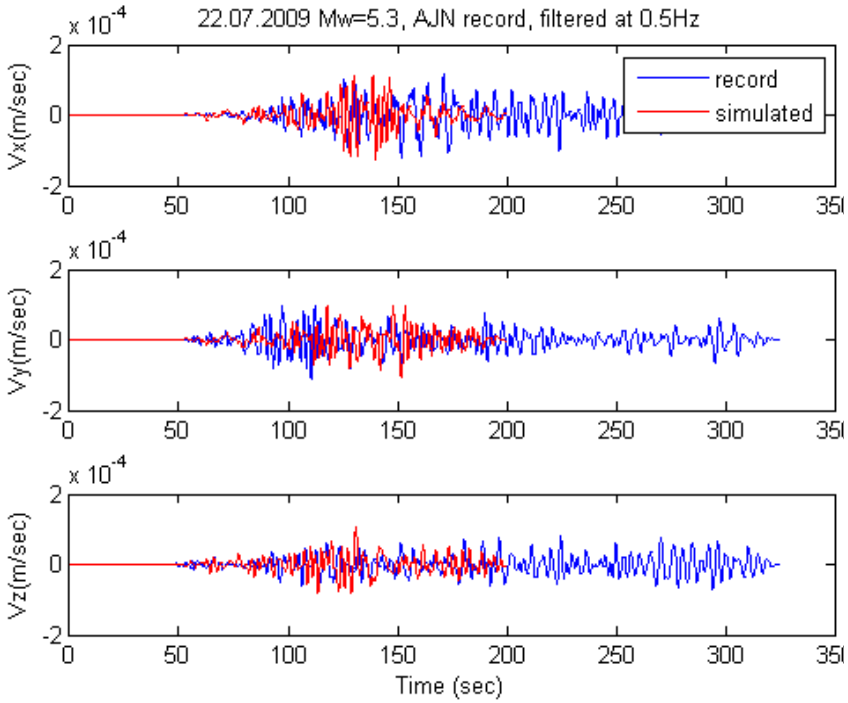


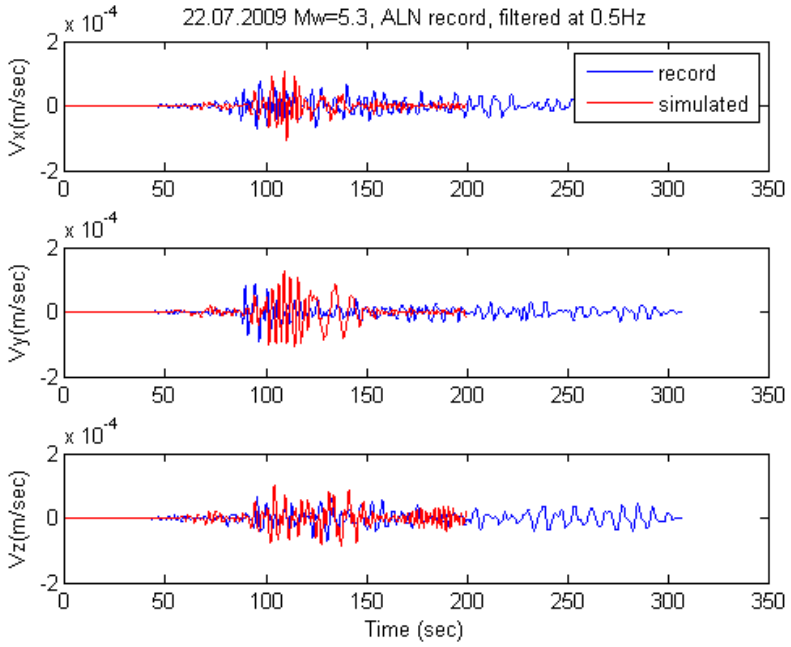


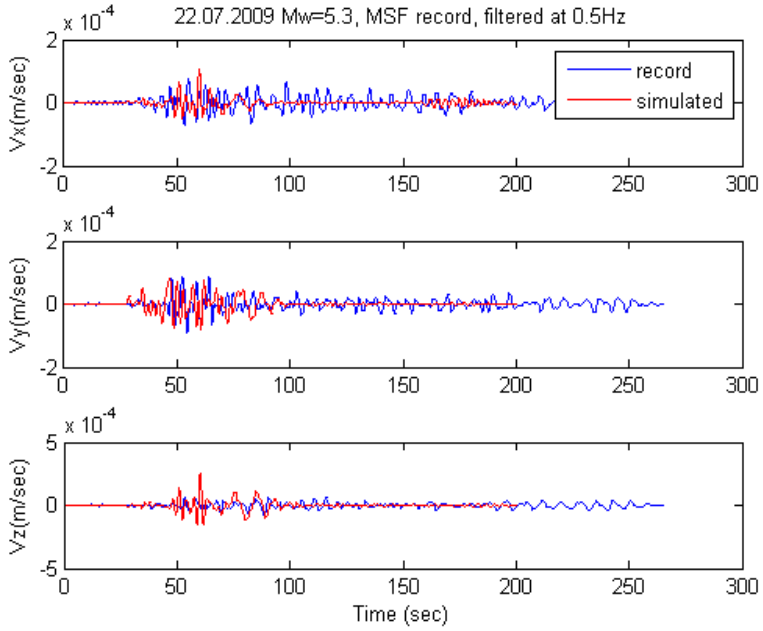


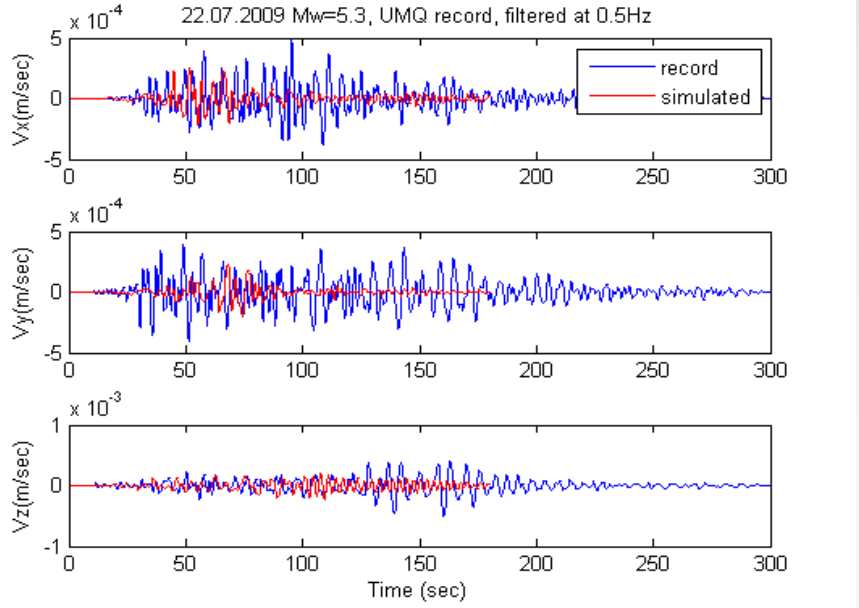
The 22.07.2009 event close to the Zendan-Minab fault

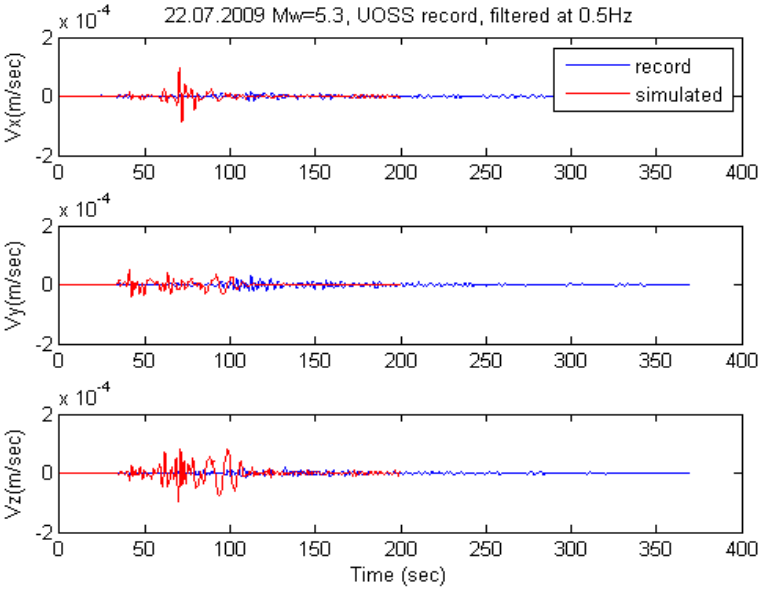








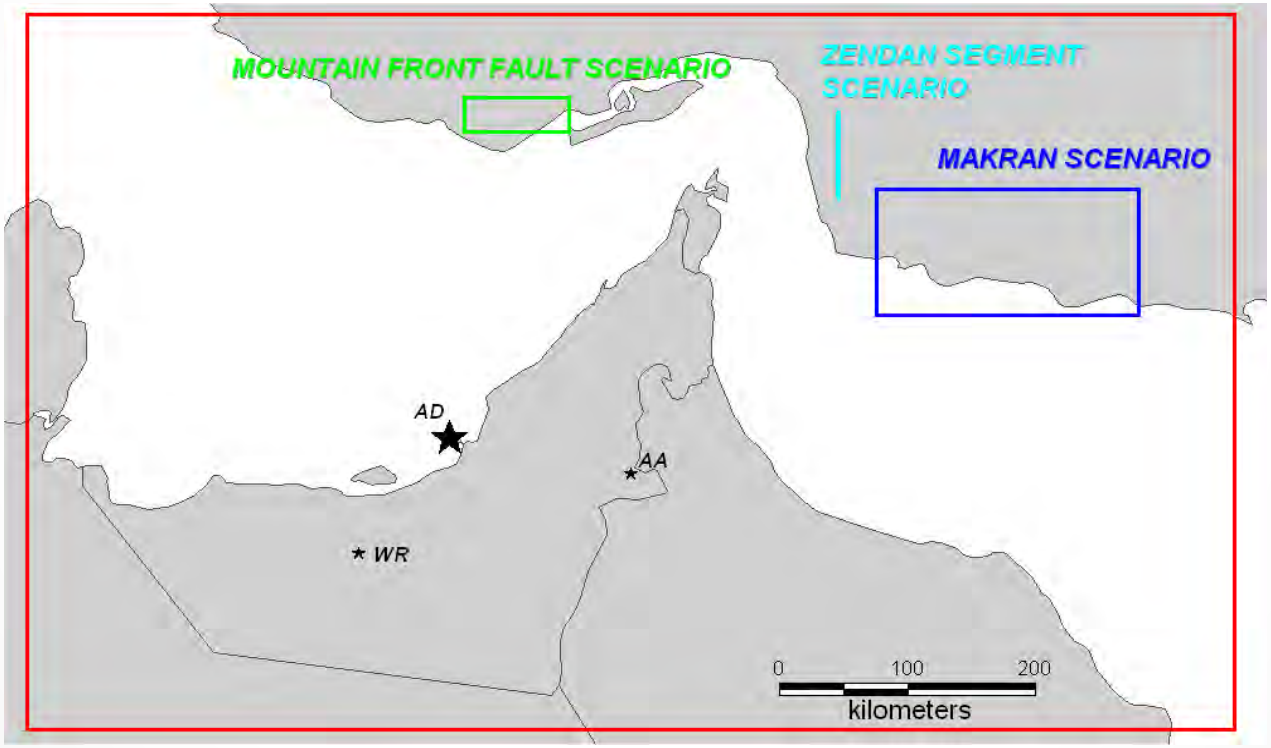




For this event, simulations provided a good fit with the NCMS data, however the simulation obtained for the UOSS station, especially for the EW and vertical components was not satisfactory. Considering the fact that MSF and UOSS stations were relatively close to each other and that a good fit was obtained for the MSF station, we did not consider the UOSS station recording in the validation process supposing that some localized site effects or the station setup issues might be the reason of the discrepancy.

REGIONAL WAVE PROPAGATION MODELING

EARTHQUAKE SOURCE ZONES AND SCENARIO EARTHQUAKES



Earthquake scenarios considered for long period waveform modeling.
AD: Abu Dhabi city location, AA: Al Ain city location, WR: Western Region location

REGIONAL WAVE PROPAGATION MODELING

EARTHQUAKE SOURCE ZONES AND SCENARIO EARTHQUAKES

EARTHQUAKE SOURCE MODELS ADOPTED IN SIMULATIONS

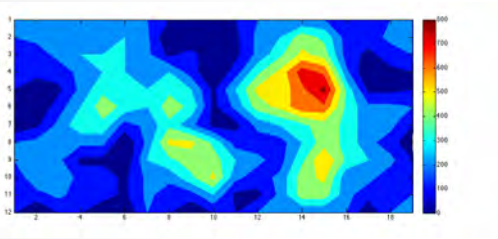
Earthquake Source Zone	**Earthquake**	**M_w**	**Mechanism**	**Reference**
Makran	Tokachi-oki (Japan) 2003	8.21	Subduction zone	Koketsu et al. (2004)
	Chile (Chile) 2010	8.80		Sladen (online)
Zagros	Tabas (Iran) 1978	7.10	Reverse	Hartzell and Mendoza (1991)
	Nahanni 2 (Canada) 1985	6.69		Hartzell et al (1994)
Zendan-Minab	Parkfield (USA) 2004	6.06	Right lateral strike slip	Custodio et al (2005)
	Kobe (Japan) 1995	6.94		Wald (1996)

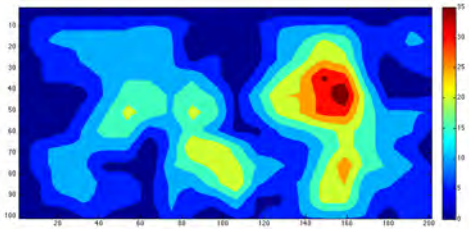
Source scaling parameters

Earthquake	Mw original	Mw target	Fault size original	Fault size target	Grid size original	Grid size target
Tokachi-oki (Japan) 2003	8.21	8.5	120km x 100km	200km x 100km	10km x 10km	1km x 1km
Chile (Chile) 2010	8.80	8.5	570km x 180km	200km x 100km	30km x 15km	1km x 1km
Tabas (Iran) 1978	7.09	7.3	95km x 45km	80km x 40km	4.75km x 4.5km	1km x 1km
Nahanni 2 (Canada) 1985	6.69	7.3	40km x 17.40km	100km x 30km	2.66km x 1.74km	1km x 1km
Parkfield (USA) 2004	6.06	6.9	40 km x 15km	60km x 20km	1.9km x 1.7km	1km x 1km
Kobe (Japan) 1995	6.94	6.9	60km x 20km	60km x 20km	3.33km x 2.5km	1km x 1km

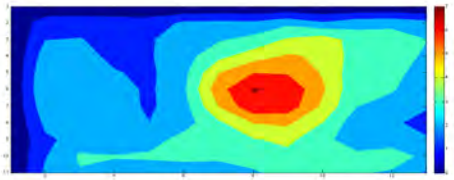
Source Models

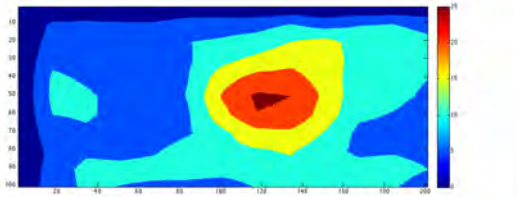
Makran scenarios





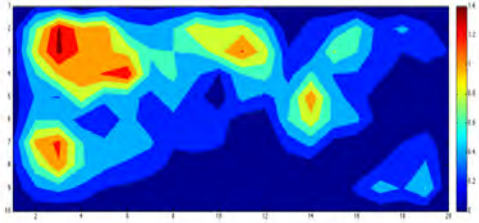
2010 Mw 8.8 Chile

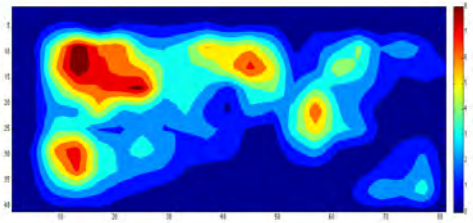




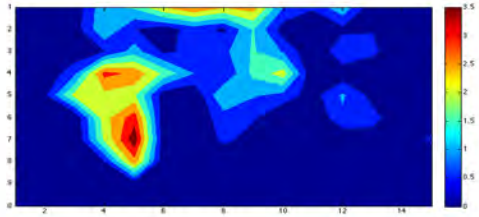
2003, Mw 8.21 Tokachi-oki

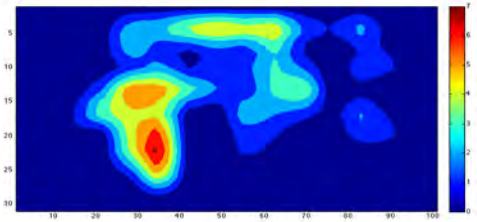
Zagros scenarios





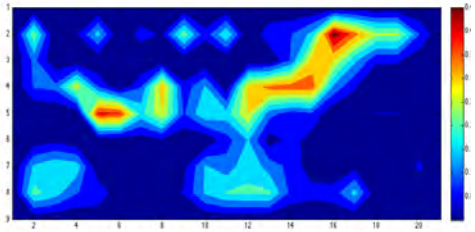
1978 Mw 7.09 Tabas

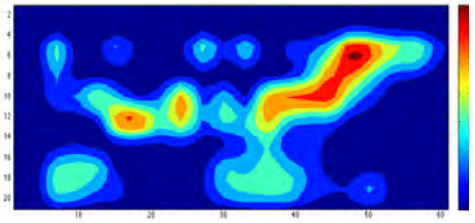




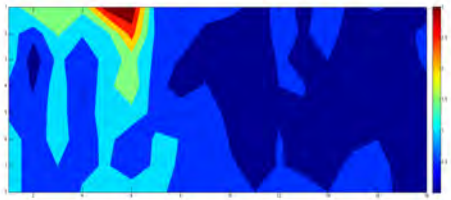
1985 Mw 6.69 Nahanni 2

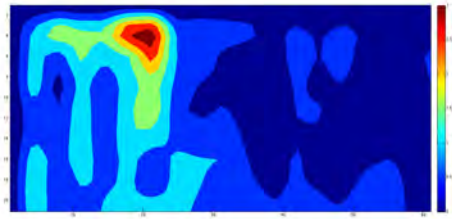
Zendan Minab scenarios





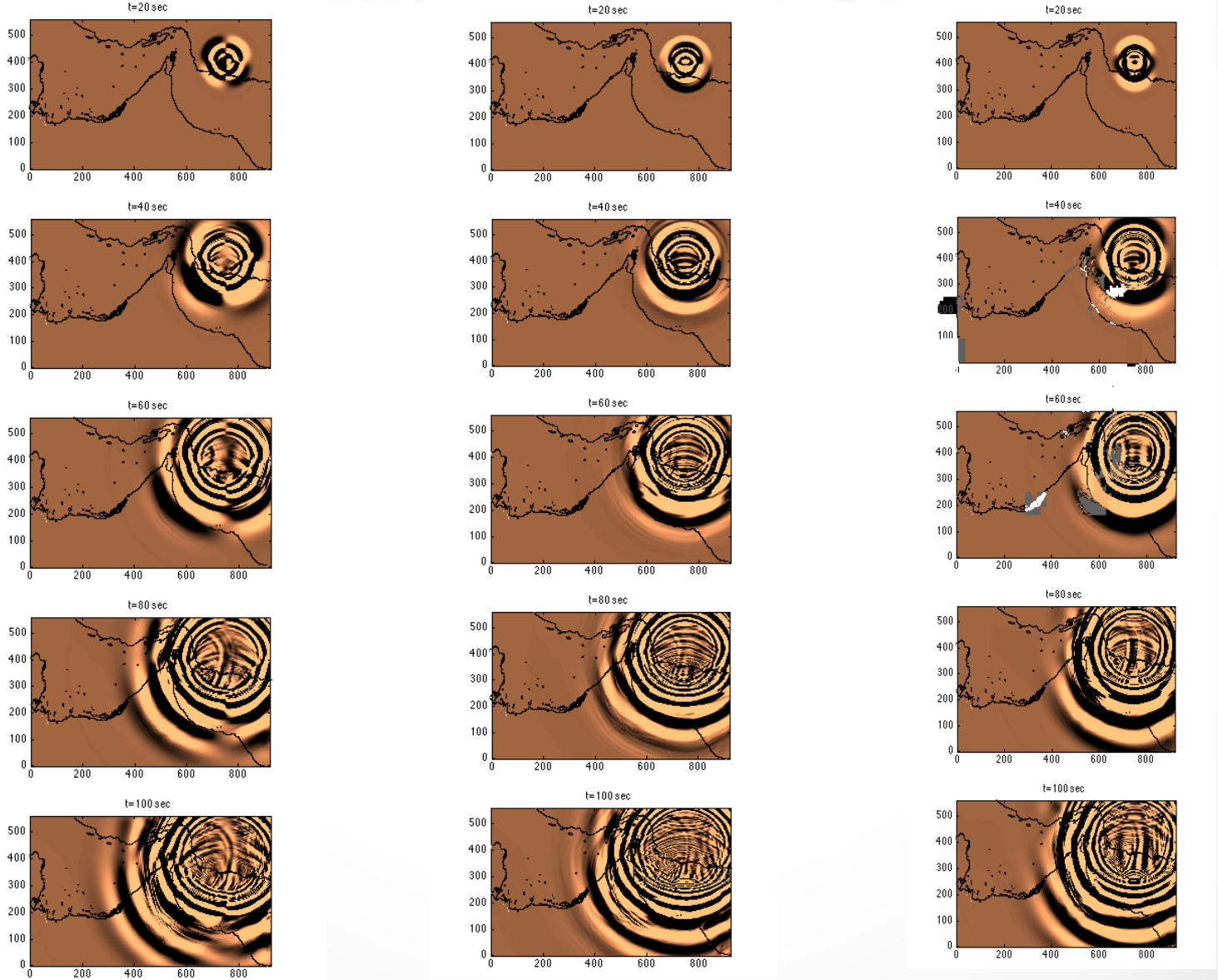
2004, Mw 6.06 Parkfield



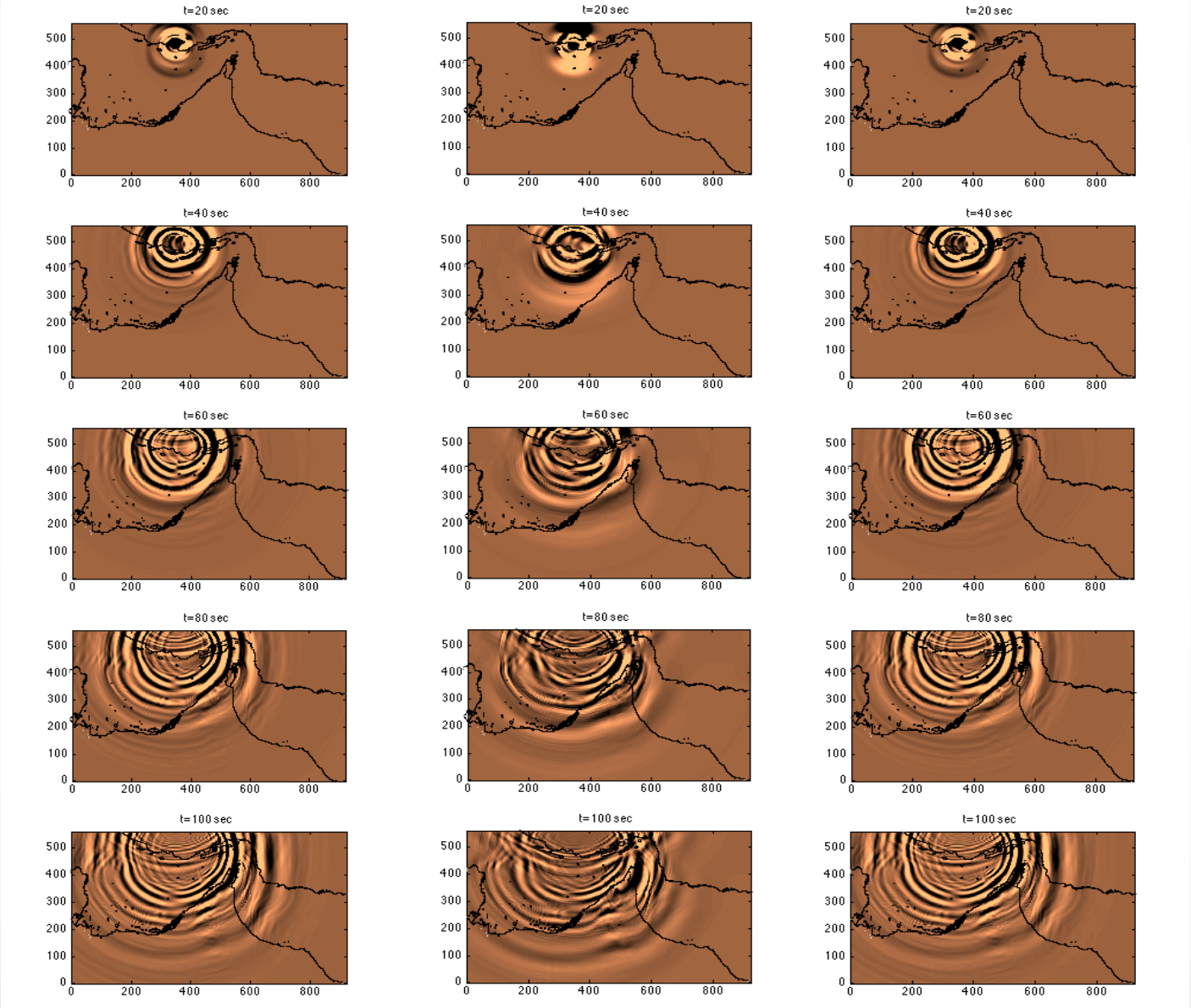


1995, Mw 6.94 Kobe

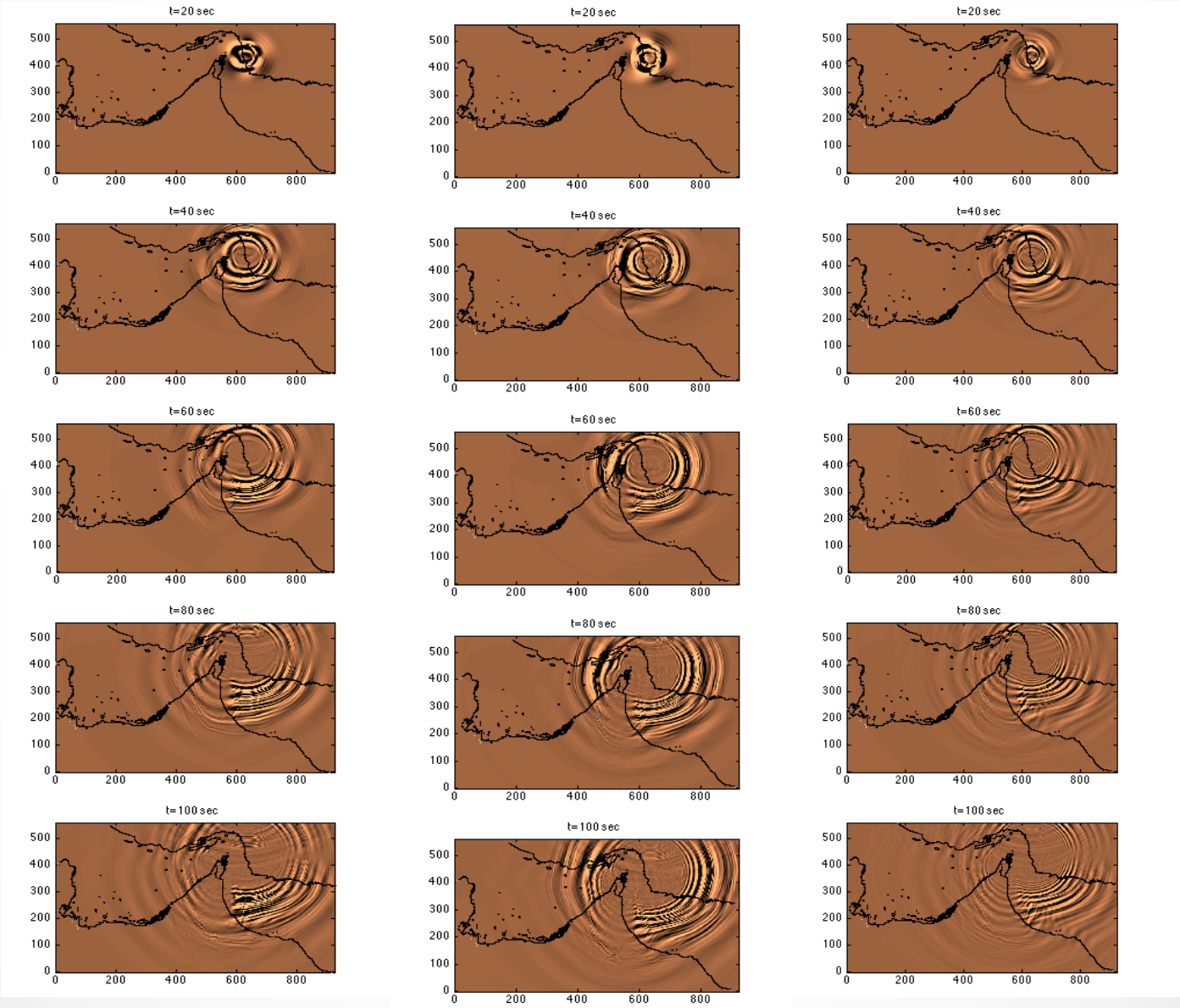
Simulation Results
Makran Tokachi-Oki



Simulation Results
Zagros Tabas



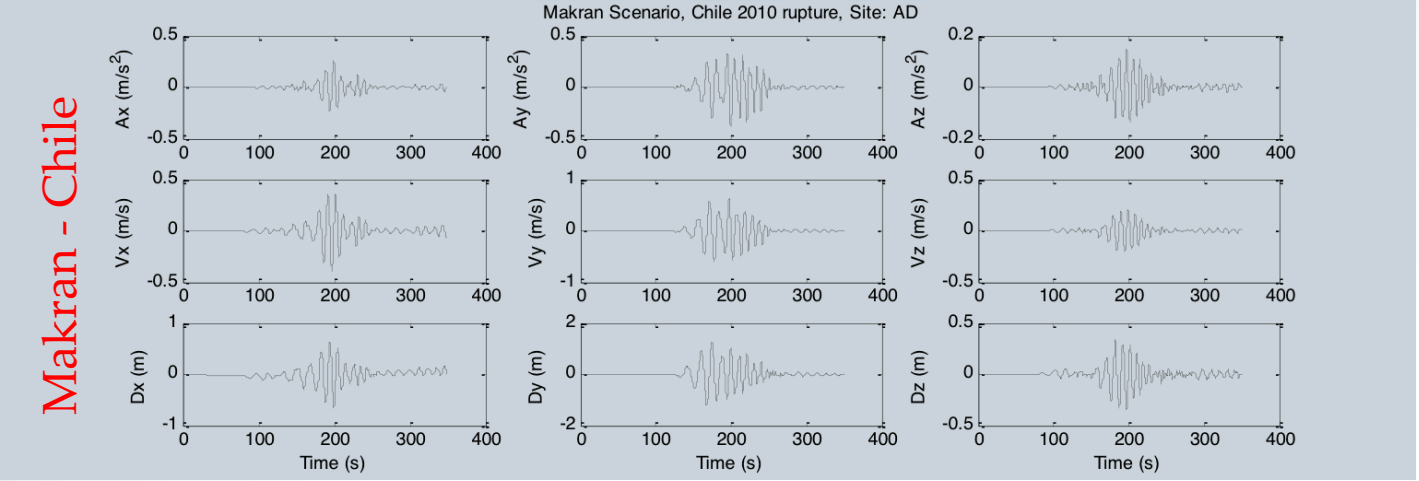
Simulation Results
Zendan-Minab Kobe



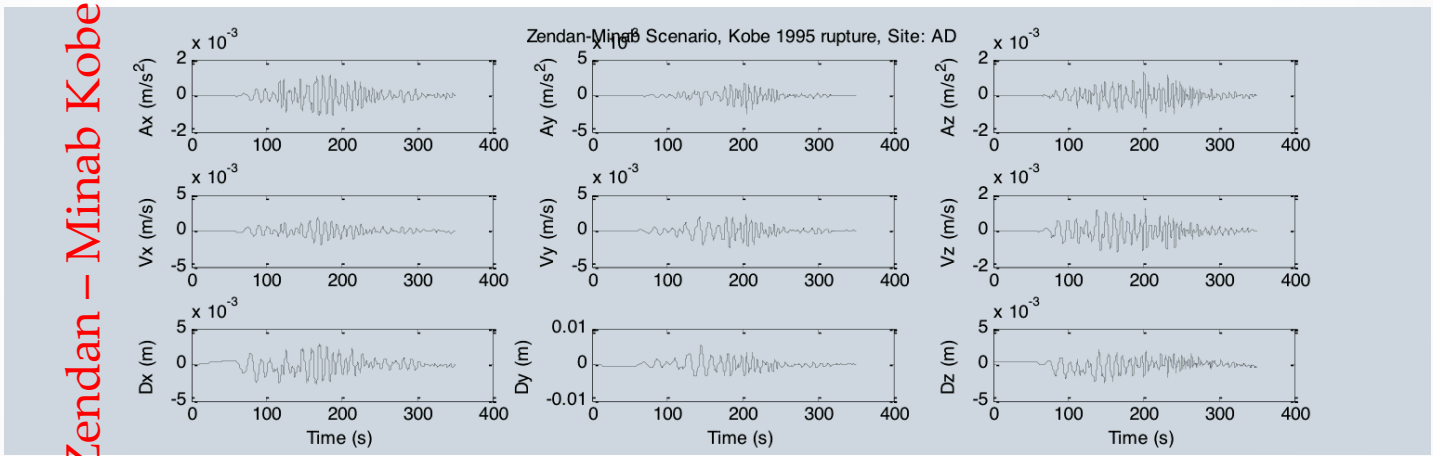
Waveforms

Abu Dhabi

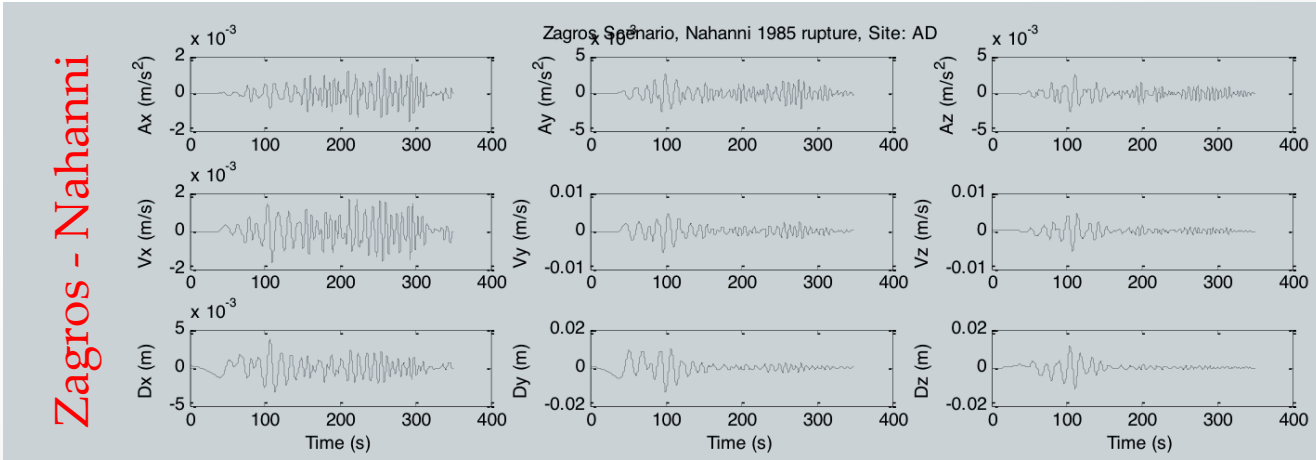
Makran - Chile



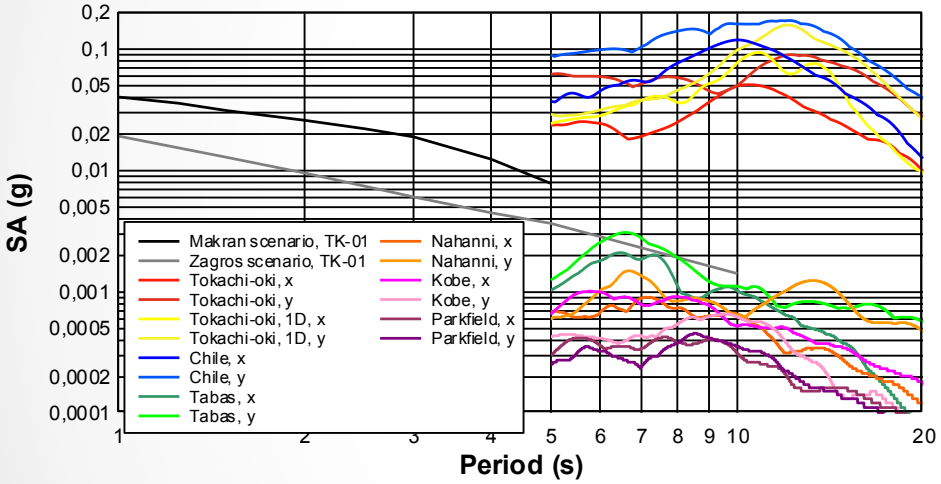
Zendan – Minab Kobe

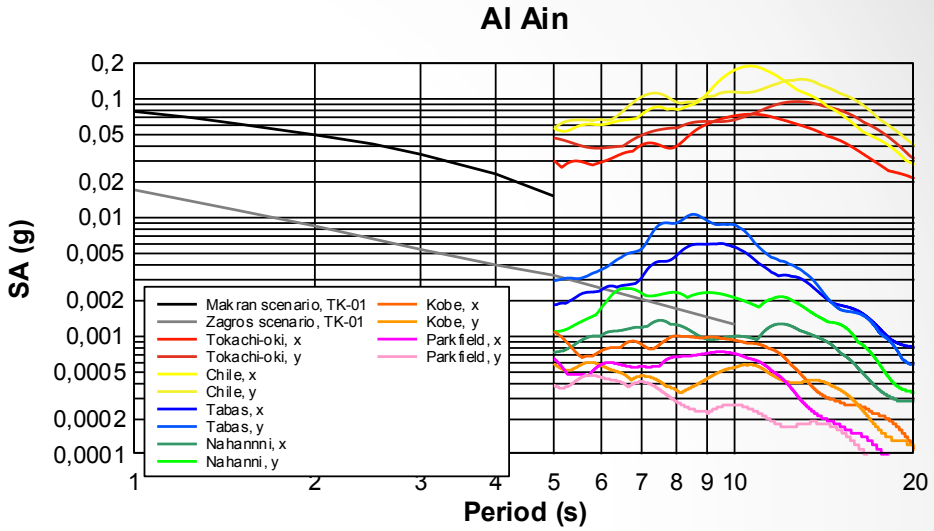


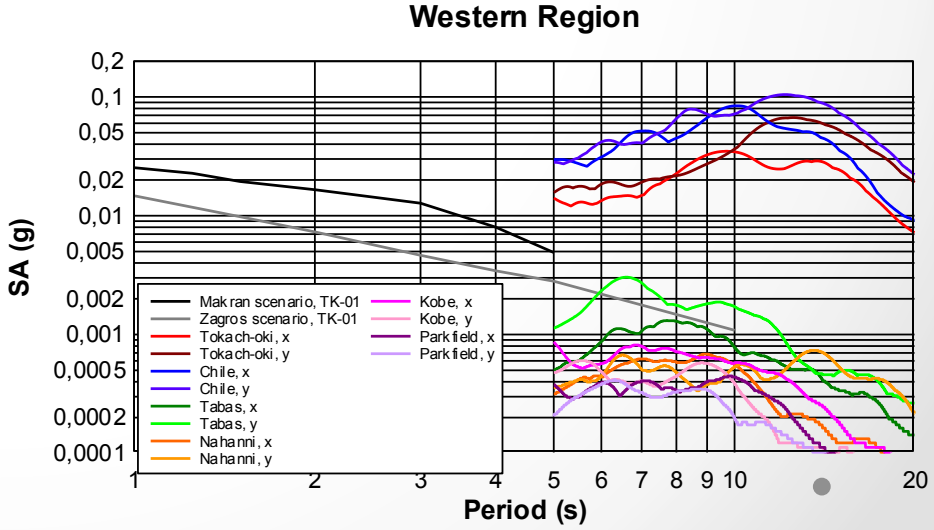
Zagros - Nahanni



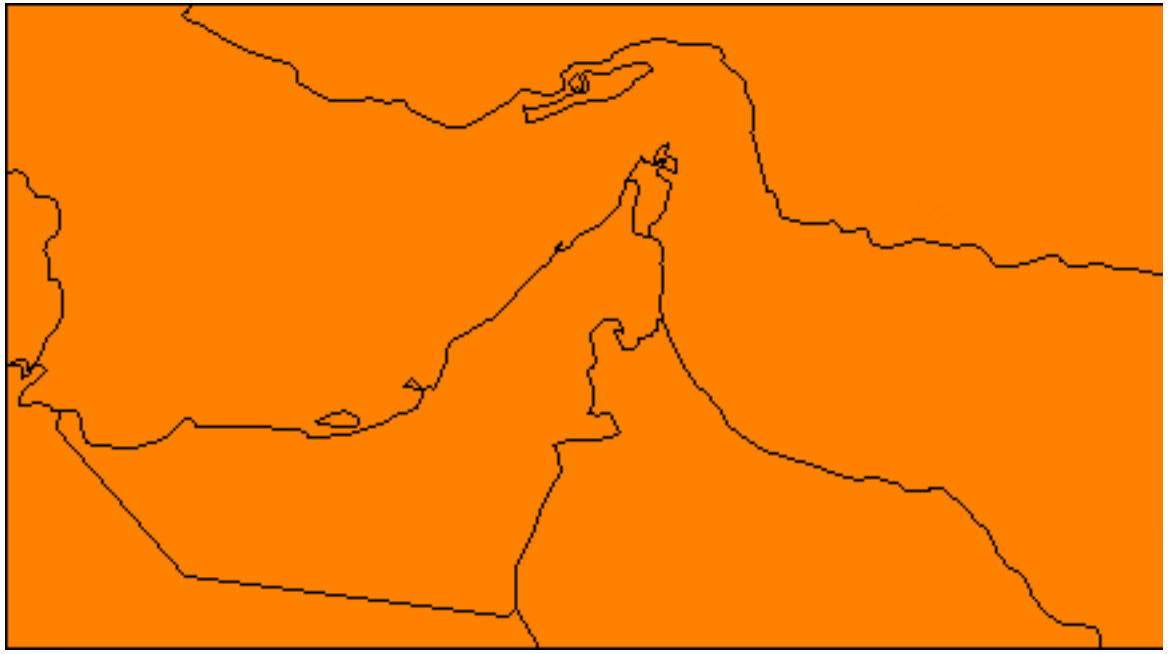
Comparison of Response Spectra from Earthquake Hazard Studies and Wave Propagation Simulations







Makran – Chile Scenario



- Velocities in EW Direction

Makran Tikochi-Oki Scenario

- Velocities in EW Direction

Zagros – Tabas Scenario

- Velocities in EW Direction

Zagros Nahanni Scenario

- Velocities in EW Direction

Zendan - Minab Kobe Scenario

- Velocities in EW Direction

Zendan – Minab Parkfield Scenario

- Velocities in EW Direction

SUMMARY OF FINDINGS

- Spectral accelerations of simulations for earthquakes from the Zagros zone have comparable levels with the spectral accelerations estimated using GMPEs in the period range 5 to 10s.

- For periods longer than 10s, for which the current GMPEs do not provide estimations, it is observed that the simulated spectral accelerations continue with the same trend of the GMPEs.

- Earthquakes originating from Makran tend to produce spectral accelerations larger than those estimated by the GMPEs for periods longer than 5s. The current GMPEs for the subduction zones are defined for periods shorter than 5s. Therefore a direct comparison of spectral accelerations from simulations and GMPEs are in fact not justified. Still the long period simulations estimate spectral accelerations clearly above the tended levels from GMPEs.

SUMMARY OF FINDINGS

- The Makran zone controls the long-period earthquake hazard in the Emirate of Abu Dhabi. Therefore large spectral accelerations at periods 10-15s, indicated by simulation results, may have implications for the long-period structures, particularly for existing or planned high-rise buildings.

- The peaks that we see in the response spectra are controlled by the surface waves in the crustal wave-guide. The low velocity sedimentary layer down to 8 km guides these waves.

- Simulated waveforms are intended for use in the design of new and in the performance and seismic vulnerability assessment of existing tall buildings and other long period structures in the Emirate of Abu Dhabi. They are critical for structures with natural periods above 5s.

- A study on assessment of long-period hazard in the UAE is needee.