ABSTRACT
The damaging 1999 Athens earthquake of Mw=5.9 occurred at about 20 km from the city center. The intensity distribution in the capital, ranging from V to IX, was quite irregular due to combination of the source, path and site effects. The 3D-stations temporary network, installed in Athens by the University of Patras, recorded more than 400 aftershocks. The horizontal-to-vertical spectral ratios from the 2D selected aftershock records provided site classification. The most significant anomaly (HV exceeding 4 in the frequency range 1-4 Hz) was found at the Ano Liosia site, belonging to the most heavily damaged zones with intensity IX. The site is situated in a shallow basin whose surface extent is about 44 km² and the maximum depth is of about 150 m. The basin is filled with basically 3 layers. The topmost layer contains alluvium and soft soil, the second one consists of stiff soil and alternations of conglomerates, clay and sand, while the third layer is represented by Neogene formations like marl, marly limestone and sandstone. The bedrock of the basin consists of Triassic limestone and schist. Borders of the basin, where the topmost layer directly overlies the bedrock, are locally quite steep. Based on geophysical data (Vs, Vp) the earthquake was located in the basin. The 2D finite-difference techniques were used, and significant edge effects were revealed. No recording of the mainshock is available in Ano Liosia. Nevertheless, based on the fine-grid composite source model, validated by the existing strong motion records in Athens, we found that the bedrock motion in Ano Liosia had its PGA ranging from 0.2 to 0.3 g, resulting from the relatively small epicentral distance (10 km) and the forward source directivity. The source and site effects were combined with each other by a hybrid technique (Oprsal and Zahradnik, JGR 2002), allowing fast full-wave 3D calculations up to 10-20 Hz on a standard personal computer, and showing that the combined source and site effect in Ano Liosia might provide the PGA values locally exceeding 0.6 g.

The 2-step hybrid method takes into account the source path and site effects:
- The 1st step is calculated by PEXT finite-source modeling
- The second step is computed by FD for a local site

The 1st step: The particle motion at the double-planed excitation-box is saved on disc. The computation may be performed up to very high frequency by any (dis)location method (in our case Discrete Wavenumber method or DWN-FD). The model contains the excitation box area from the 1st step. The local topography and complex structures are added inside the excitation box. The computation performs in three different areas (I-II-III) (see figure above). For details see [1,2].

The 2nd step: It is computed by FD method on a coarse grid. This model contains the excitation box area from the 1st step. The local topography and complex structures are added inside the excitation box. The computation performs in three different areas (I-II-III) (see figure above). For details see [1,2].

A recipe:
- Calculate 3D wavefield due to source and crustal part
- Solve 3D site model by FD, thus you get combined source-path-site effects

Numerical methods:
1st step:
- Computed PEXT finite-extent source (see [2])
- Composites source modeling up to 2.8 Hz yields deterministic envelopes of accelerograms
- Radial rupture propagation: rupture velocity varies up to 10% around the nominal value
- Acceleration spectral plateau is extrapolated up to 6 Hz from the deterministic part (2.0-2.8 Hz) by a Gaussian noise
- Complete Green’s functions computed by DWN on 1D structure
- Source 1st layer outcropping points are interpolated into the 2nd step excitation source

2nd step:
The PSi-3D FD SCHEME (see [1]); f = f = (0 0) Hz ≤ 6.0 Hz
- The FD algorithm is easy to implement:
  - on flat earth by vacuum formalism
  - free surface by vacuum formalism
  - high efficiency on irregular grid
  - Easy employment of topography
  - High efficiency on irregular grid

Other features:
- stable at high (\nu/n) contents
- stable at low (\nu/n) contents

Conclusions:
1) HYBRID approach allows joint treatment of finite-extent source, path and site effect (here up to 6 Hz)
2) The 3D input (bedrock) motion calculated by PEXT method validated by comparison of synthetic and observed strong motion records in the other sites in Athens
3) Ano Liosia, strong damage and intensity IX – proved to be combined effect of promiximity and directivity of source, and complex 3D site effects.