EGU General Assembly 2022

Vienna, Austria & Online | 23–27 May 2022

Seismic shaking scenarios for city of Dubrovnik, Croatia

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Introduction

- SE part of Adriatic Sea → wider Dubrovnik area - most tectonically active region of Croatia
    - strongest event: 6th April 1667 (Great Dubrovnik earthquake, M = 6.8 – 7.2)

Goal:

- simulate seismic shaking and evaluate expected ground motion for plausible earthquake scenarios

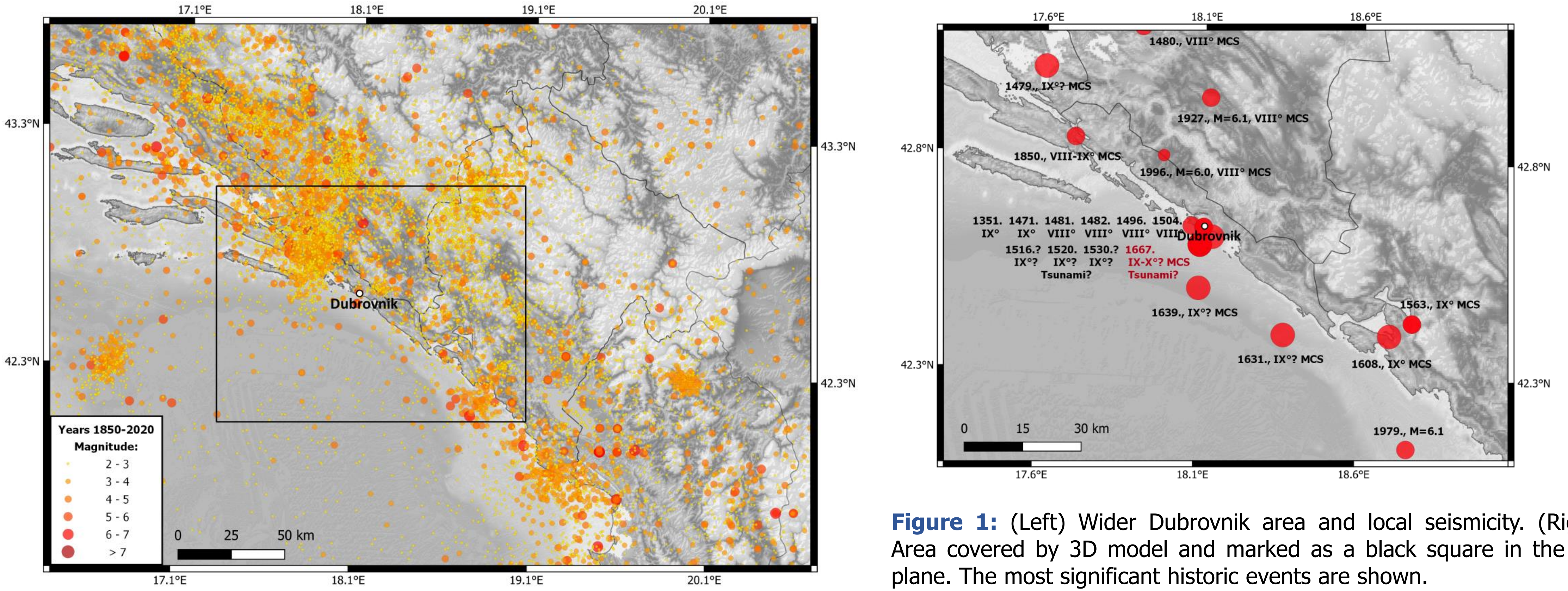


Figure 1: (Left) Wider Dubrovnik area and local seismicity. (Right) Area covered by 3D model and marked as a black square in the left plane. The most significant historic events are shown.

Workflow – Development of the 3D model

- Model:
  - covers 150 km × 110 km area
  - extends to the depth of 60 km
  - consists of three main layers: carbonates, crystalline crust and mantle

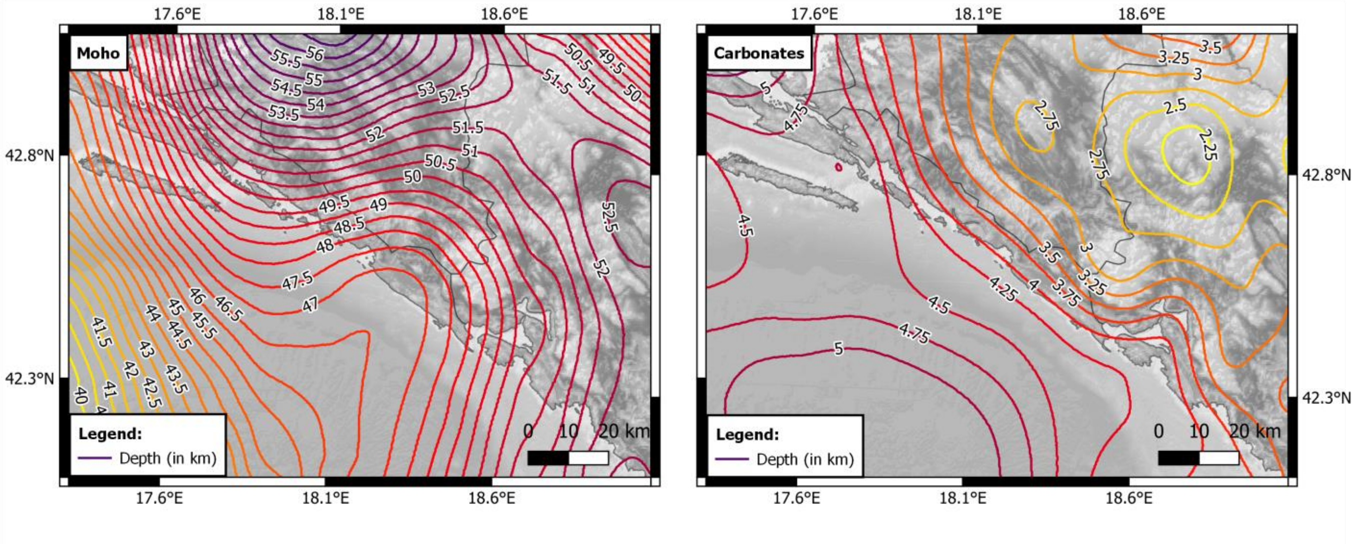


Figure 2: (Left) Moho depths from [1] used to define crust – mantle boundary in the 3D model. (Right) Carbonate depths from [2] used to define carbonates – crystalline crust boundary in the 3D model.

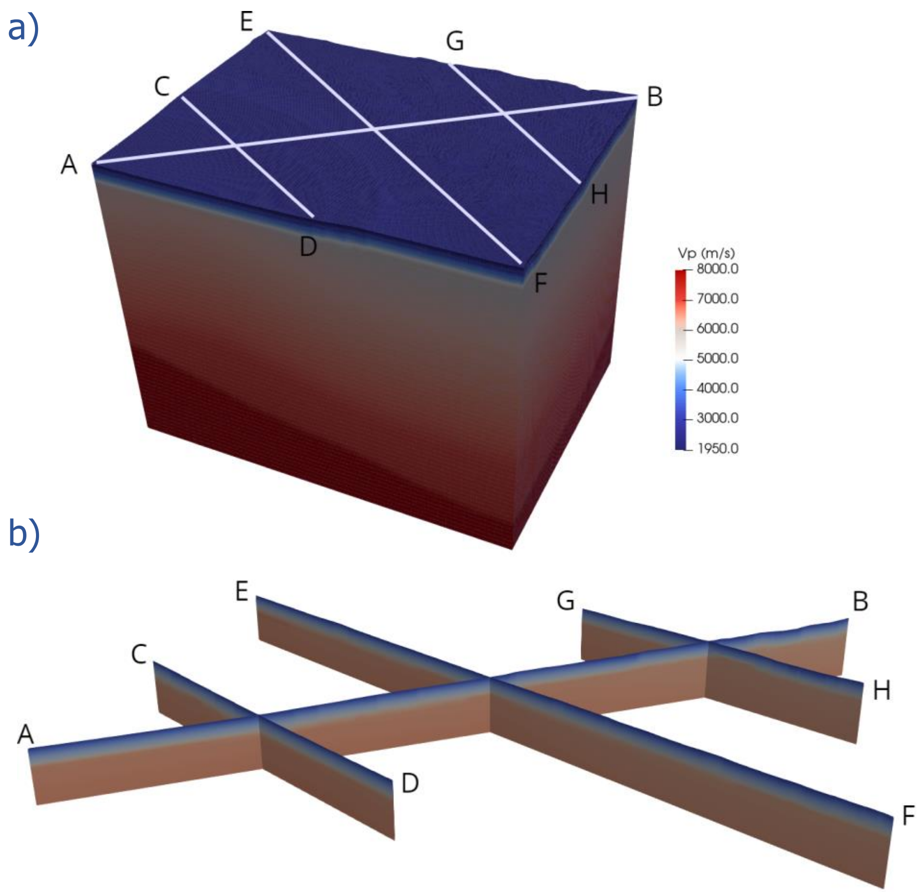
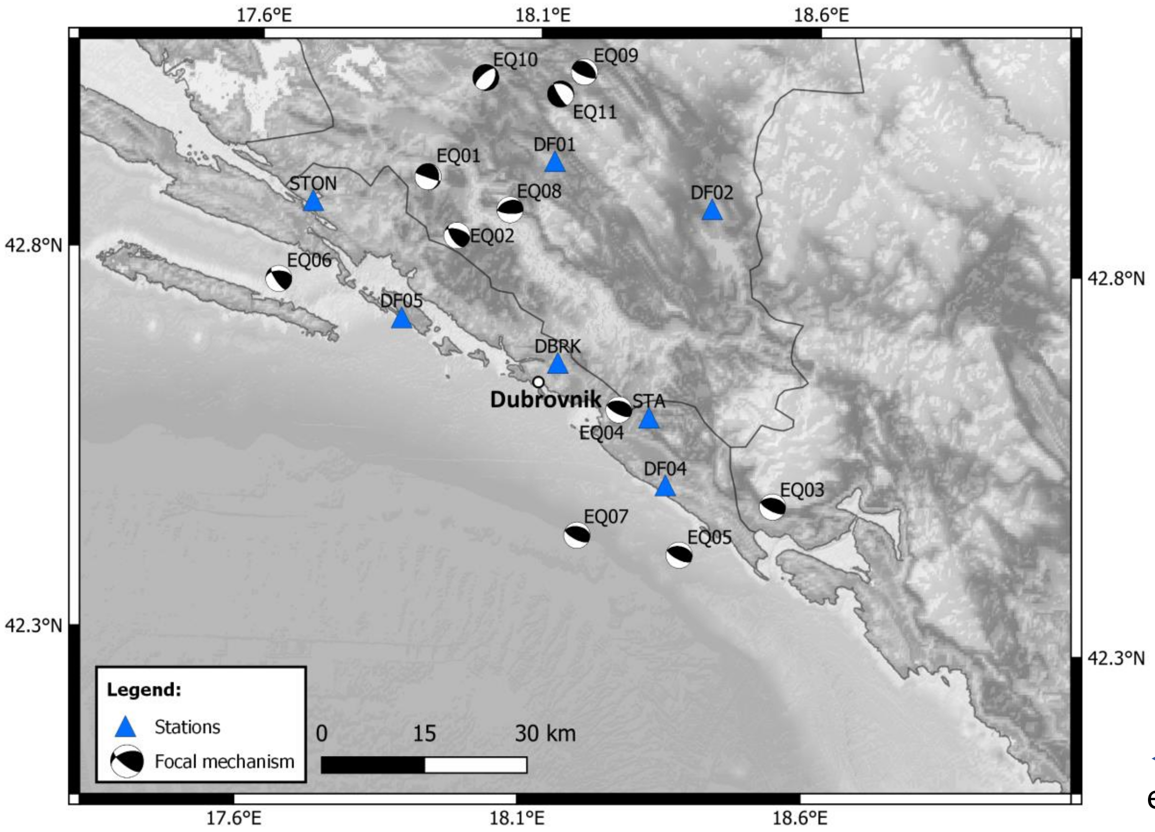


Figure 3: a) 3D P-wave velocity (Vp) model for the wider Dubrovnik area; b) Four cross sections of the model (only top 10 km are shown).

Workflow – Data and method

- Low-frequency simulation (*f* < 1Hz)
  - deterministic method – SPECFEM3D Cartesian [3, 4, 5]
  - 3D model + topography and bathymetry + attenuation
  - 8 events (3.0 < Mw < 4.4) – point force source model
  - 3 events (4.4 ≤ Mw < 6.0) – simplified finite fault model



◄ **Figure 4:** Locations and focal mechanisms of the simulated earthquakes. Blue triangles represent stations.

Table 1: Names, dates, moment magnitudes (Mw), fault-plane solutions (FPS) and depths for the events used in simulations.

Event name	Date	Mw	FPS	Depth (km)
EQ01	05-11-2013	3.4	109°/85°/76°	10
EQ02	01-05-2015	3.5	286°/47°/60°	11
EQ03	30-01-2016	3.4	280°/30°/75°	11
EQ04	28-06-2017	3.2	280°/30°/75°	10
EQ05	26-11-2018	3.7	280°/30°/75°	11
EQ06	08-11-2019	4.2	269°/37°/75°	15
EQ07	16-04-2020	3.7	280°/30°/75°	14
EQ08	24-02-2021	4.2	249°/29°/69°	10
EQ09	22-04-2022	5.7	295°/26°/92°	20
EQ10	23-04-2022	4.4	29°/30°/-107°	24
EQ11	24-04-2022	4.7	291°/20°/-125°	19

point force source model

finite-fault model

Workflow – Result validation

- Goodness of fit (GOF) scores:
    - scores from 0-100 [6]: 0-45 poor fit, 45-65 fair fit, 65-80 good fit and 80-100 excellent fit

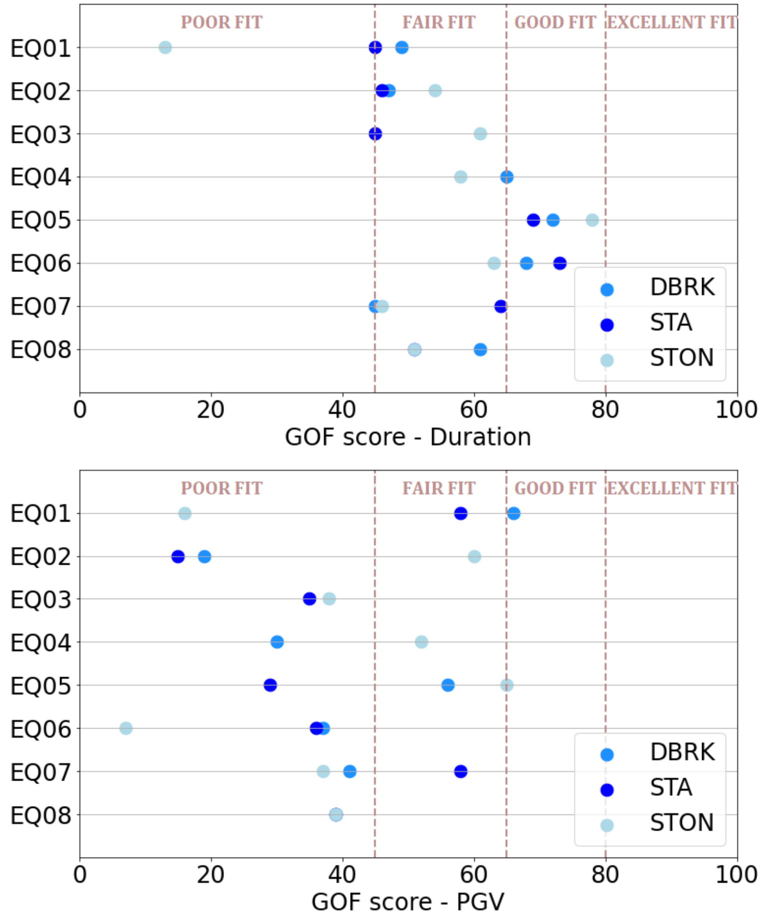


Figure 5: GOF scores for the events using point force source.

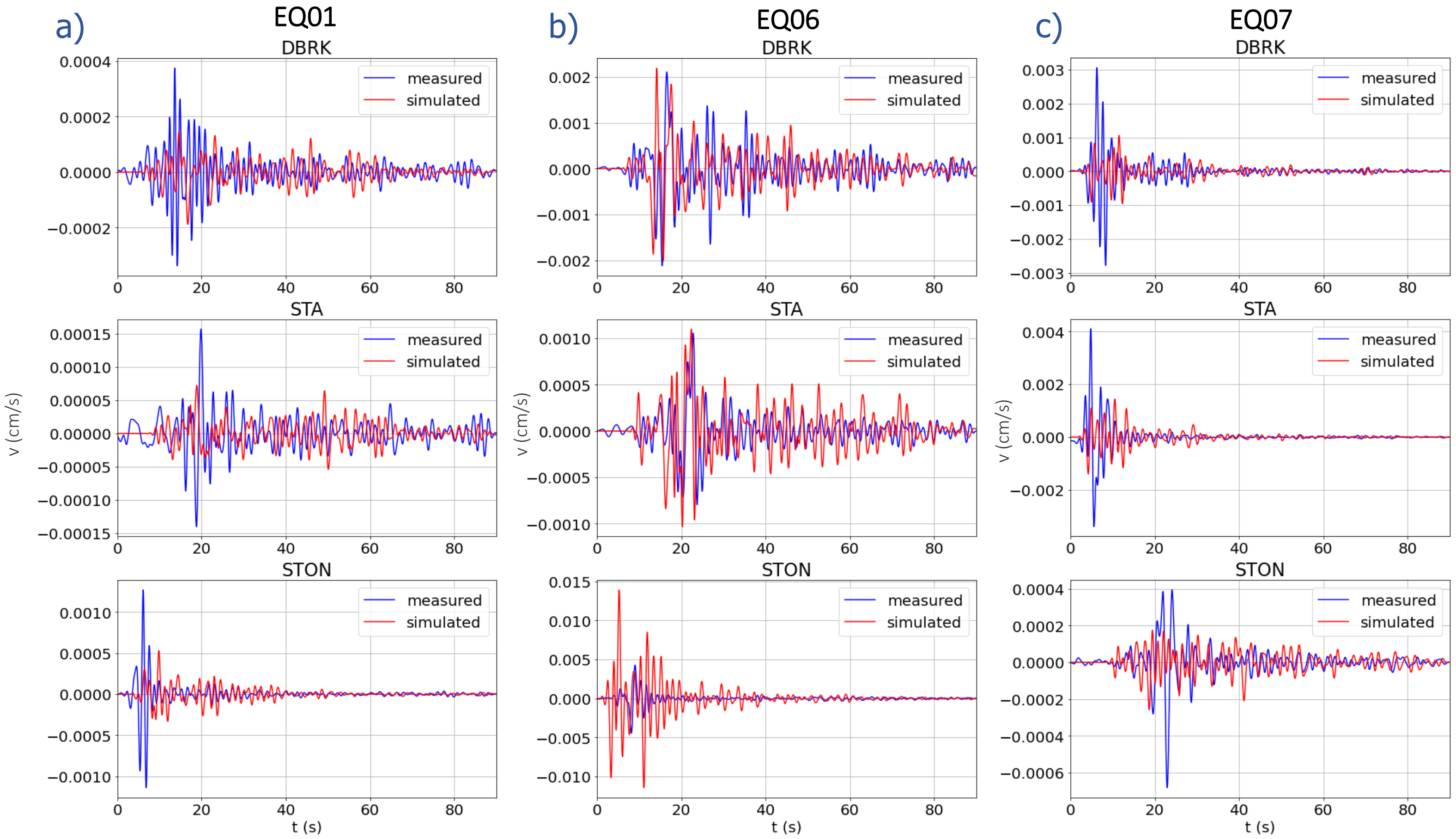


Figure 6: Vertical components of the LF seismograms (f < 1 Hz) for the a) 05-11-2013, Mw = 3.4 event; b) 08-11-2019, Mw = 4.2 event; c) 16-04-2020, Mw = 3.7 event.

Workflow – Result validation

- Goodness of fit (GOF) scores:
  - scores from 0-100 [6]: 0-45 poor fit, 45-65 fair fit, 65-80 good fit and 80-100 excellent fit

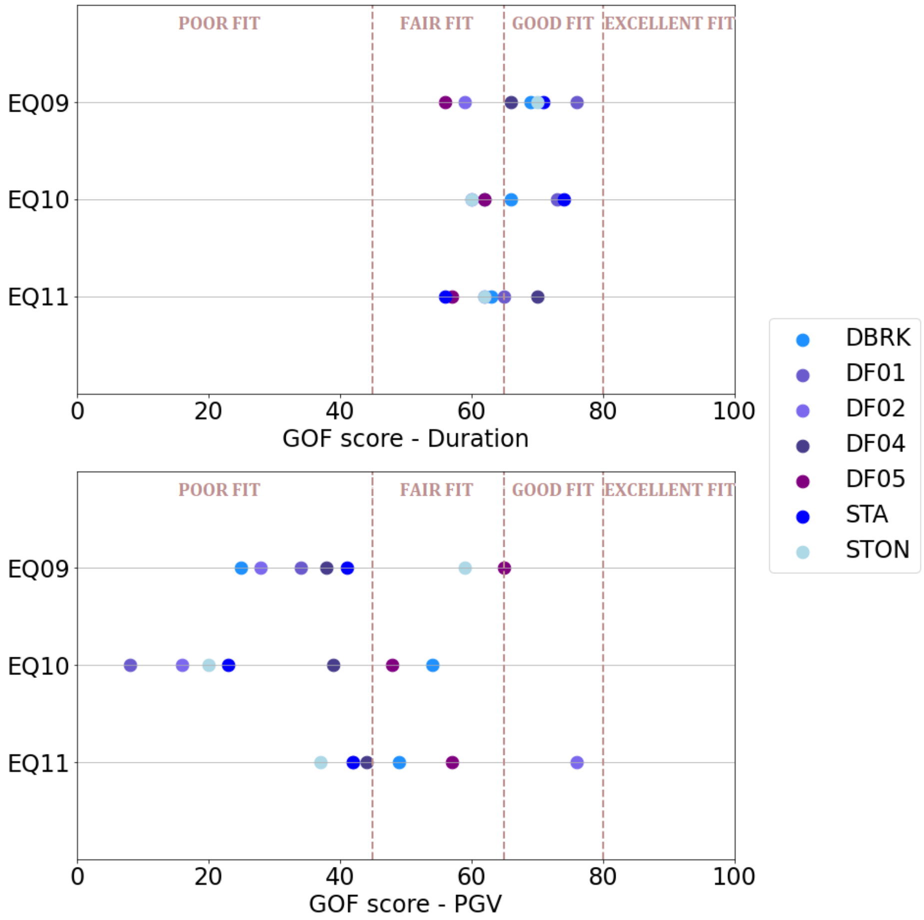
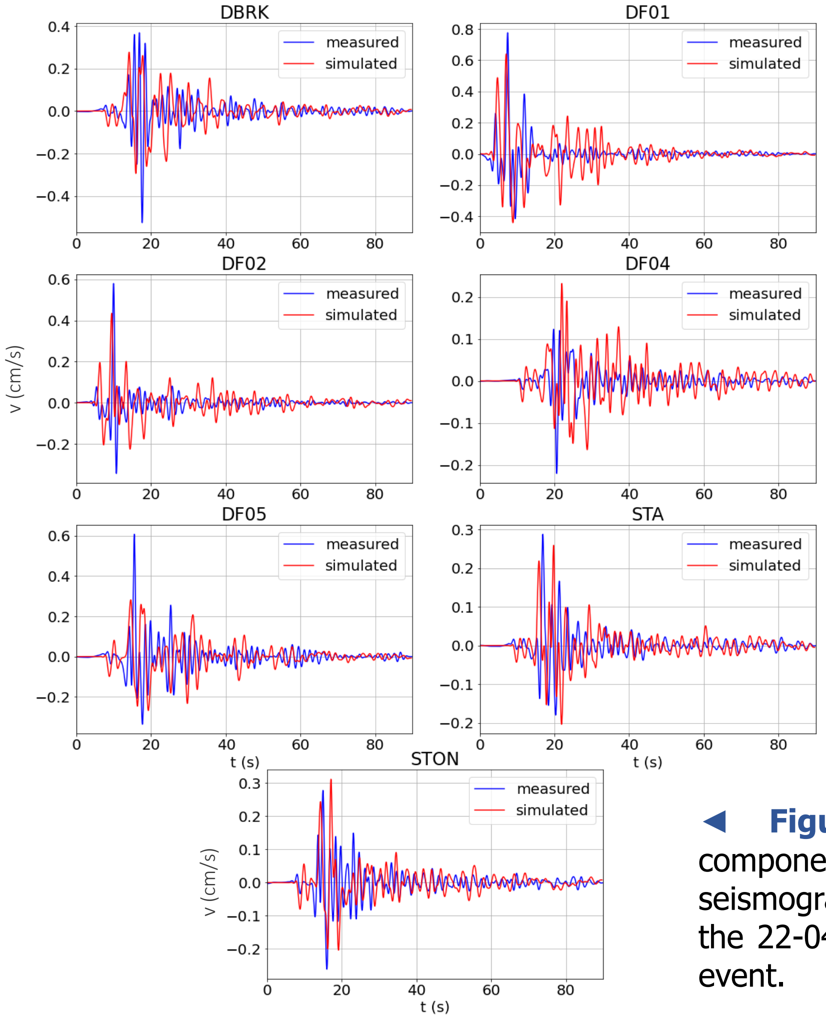
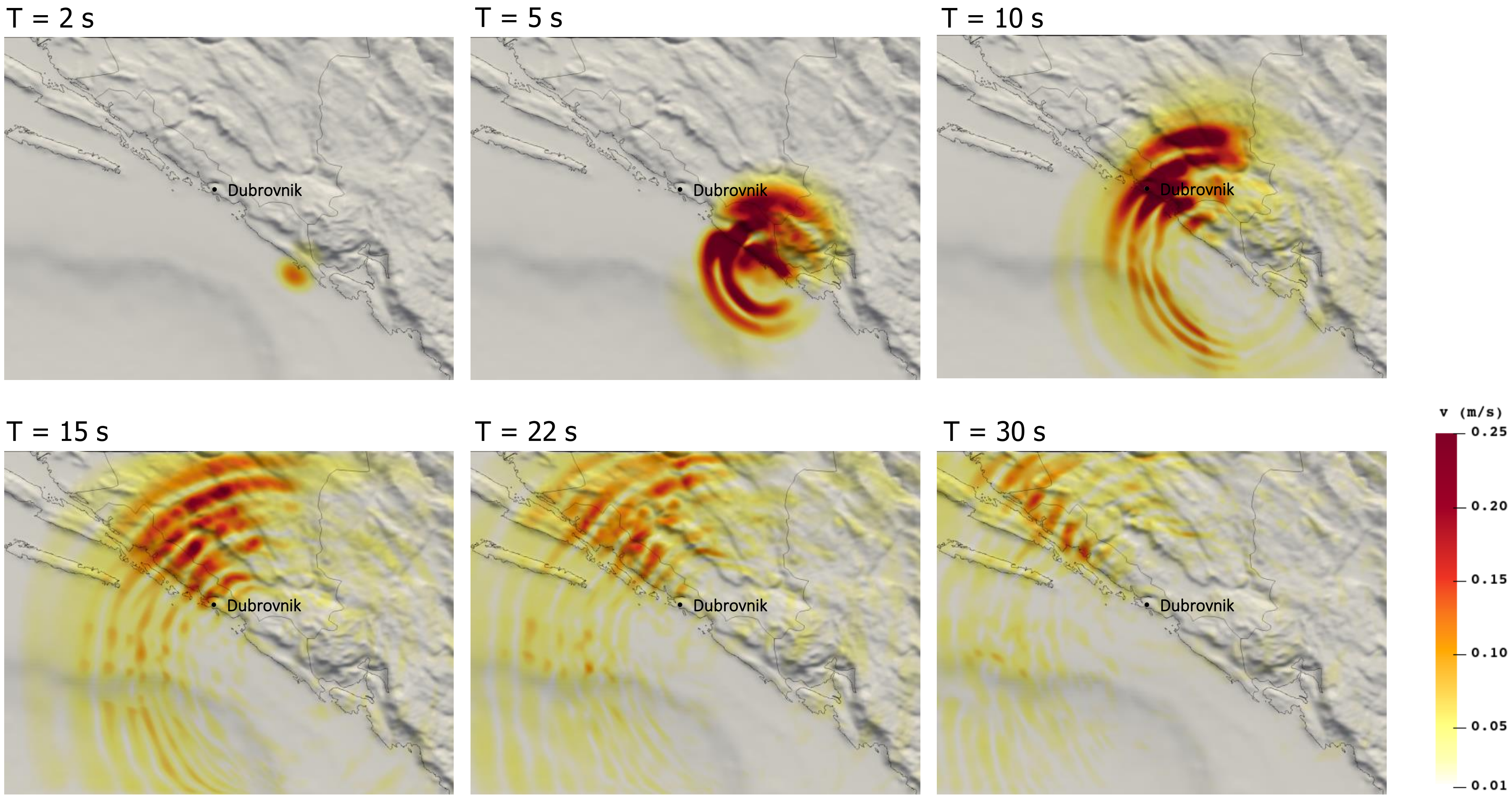


Figure 7: GOF scores for the events using finite-fault model for the source.



◄ **Figure 8:** Vertical components of the LF seismograms (f < 1 Hz) for the 22-04-2022, Mw = 5.7 event.



◄ **Figure 9:** Snapshots of the norm of the ground velocities in the simulation of a Great Dubrovnik earthquake scenario.

Source description:

Magnitude: Mw = 6.9
Location: 42.524 °N, 18.289 °E
Depth: 13 km
FPS: 300°/14°/88°

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