Ground motion simulation of the 2021 Mw 5.2 Central Adriatic earthquake

Helena Latečki[1]*, Irene Molinari[2] and Josip Stipčević[1]

[1]Department of Geophysics, Faculty of Science, University of Zagreb, Zagreb, Croatia

[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Bologna, Italy

*corresponding author: Helena Latečki (helena.latecki@gfz.hr)

SEISMICITY OF THE CENTRAL ADRIATIC SEA

Significant seismicity in the Central Adriatic Sea has been noted in a number of publications, indicating the complexity of the tectonics within the Adriatic microplate. Seismicity of this region is conditioned by the sole movements of the Adriatic microplate and the resistance of the Dinarides to those movements. Most of the seismic activity occurs offshore [1] and in the last few decades several series of earthquakes (Fig. 1.) have been detected and analyzed, most notably:

1) 1986, ML = 5.0 series in the open sea;

2) 1988, ML = 5.3 series near the island of Palagruža;

3) 2003, ML = 5.5 series near the island of Jabuka.

The most recent earthquake series in 2021 (shown in Fig. 1) implies anew higher seismic potential than what was previously assumed and opens questions regarding present-day tectonic stress distribution within the Adria microplate in general.

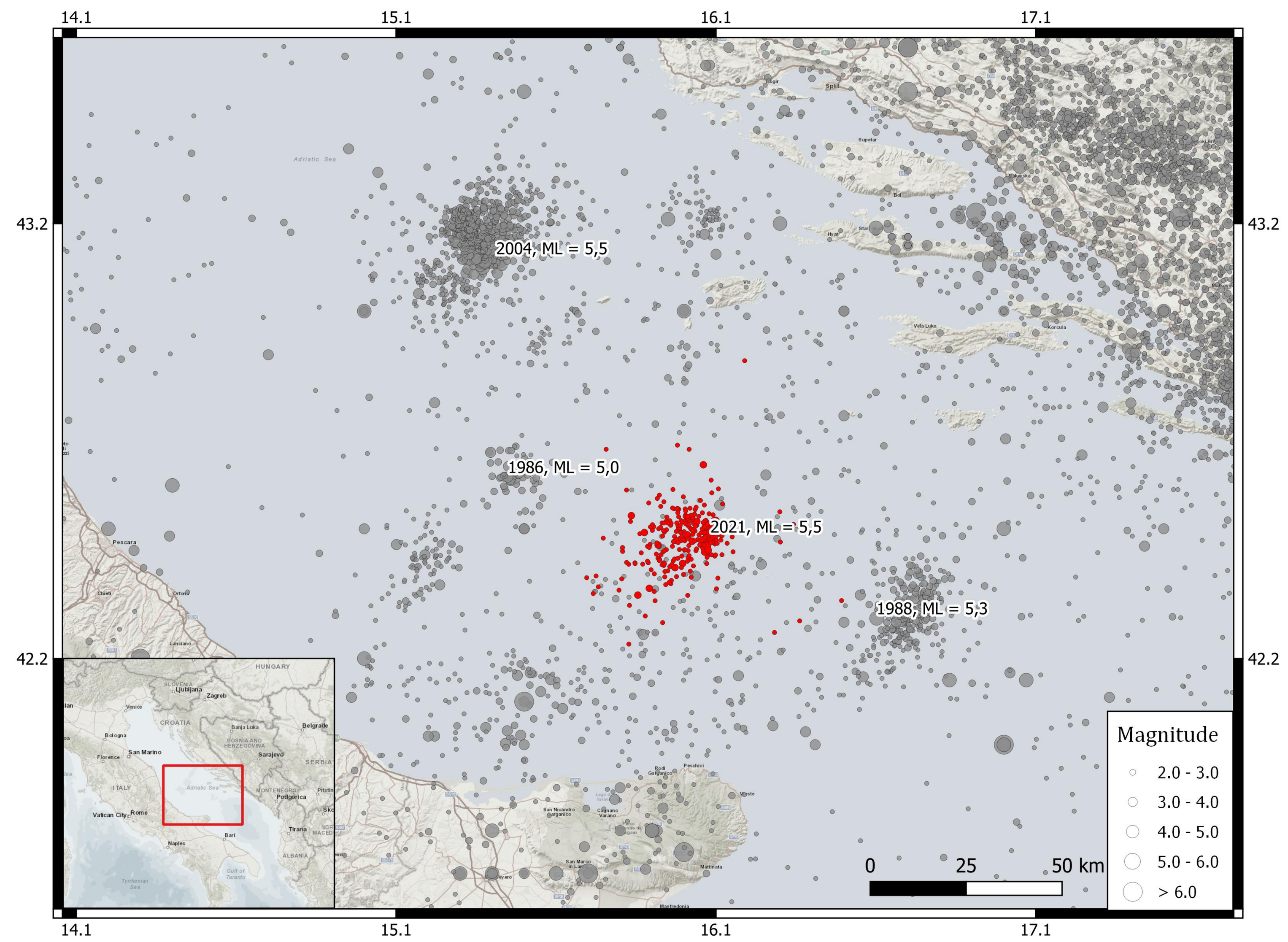

Fig. 1. Seismicity of the studied area. Epicenters of the earthquakes from the Croatian Earthquake Catalogue for years 1600 - 2022 are shown with grey circles. Red circles represent the epicenters within 50 km radius of the mainshock of the 2021 Central Adriatic earthquake sequence.

2021 CENTRAL ADRIATIC EARTHQUAKE SEQUENCE

On March 27, 2021, a Mw = 5.2 (ML = 5.5) earthquake hit Central Adriatic Sea close to the island of Vis (Croatia; Fig. 1). The earthquake was felt in central Dalmatia (Croatia) and many central-southern Italian regions (from Ancona to Foggia). The fault-plane solution of the mainshock inicates that the event occured on a reverse fault at shallow depth (less than 10 km; Fig. 2). By the end of the year 2022, more than 1000 aftershocks of varying magnitude have been located in the Croatian Earthquake Catalogue [2].

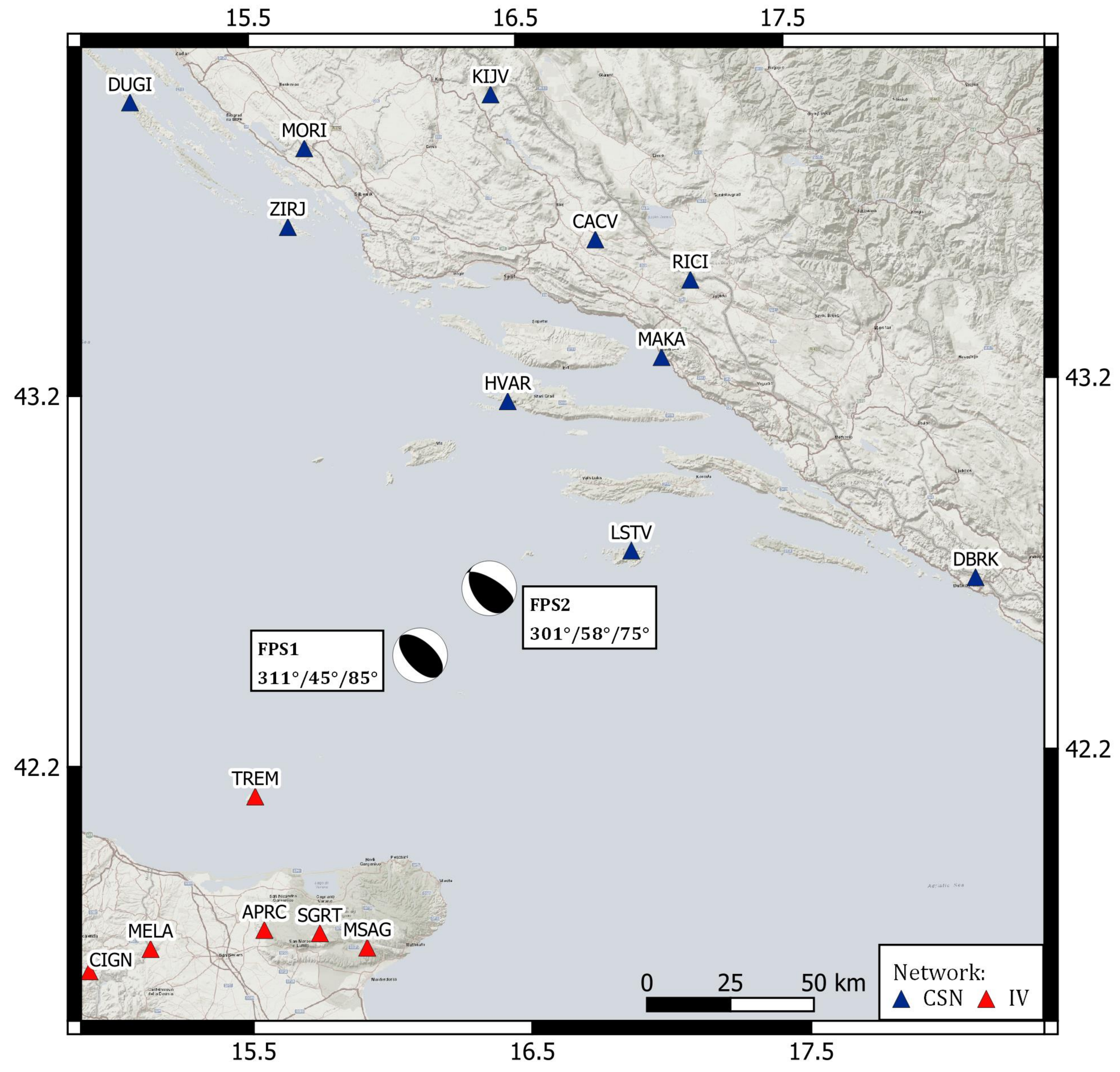

Fig. 2. Area covered by the 3D model. Triangles represent stations and two beach-balls locations and focal mechanims of the sources used in simulations.

Tab. 1. Parameters of the fault plane solutions used in simulations. Ndat is a number of defining phases used to compute solution.

	FPS1 (Ndat = 221)	FPS2 (Ndat = 262)
Origin time (UTC)	13:47:54.6	13:47:51.1
Magnitude (M_w)	5.58	5.20
Latitude (°N)	42.4960	42.6740
Longitude (°E)	16.1140	16.3697
Depth (km)	1.0	5.0

3D MODEL AND PHYSICS-BASED SEISMIC SHAKING SIMULATIONS

To evaluate the expected ground motion parameters of the event, we make use of physics-based waveform modelling and simulate the earthquake using two 3D crustal models: EPCrust [3] and our new seismic model (Fig. 3). This new model for the central Adriatic Sea was build using the available geological and geophysical data [3, 4, 5]. It honors surface topography and bathymetry and reflects most important geological features necessary to generate wave resonance effects that impact the duration and amplitude of the shaking.

We use the software package SPECFEM3D Cartesian [6] to deterministically simulate low-frequency (LF) ground motion (f < 1 Hz) for the two crustal models. In both cases, the attenuation model was scaled from the S-wave speed model following Olsen's empirical relations [7]. Source is represented as a point source with parametrization FPS1 shown in Tab. 1. and Fig. 2. We plan on simulating the waveforms using other descriptions of the source (e.g. FPS2, Fig. 2. and Tab. 1.) in order to investigate how the source parametrization affects final results.

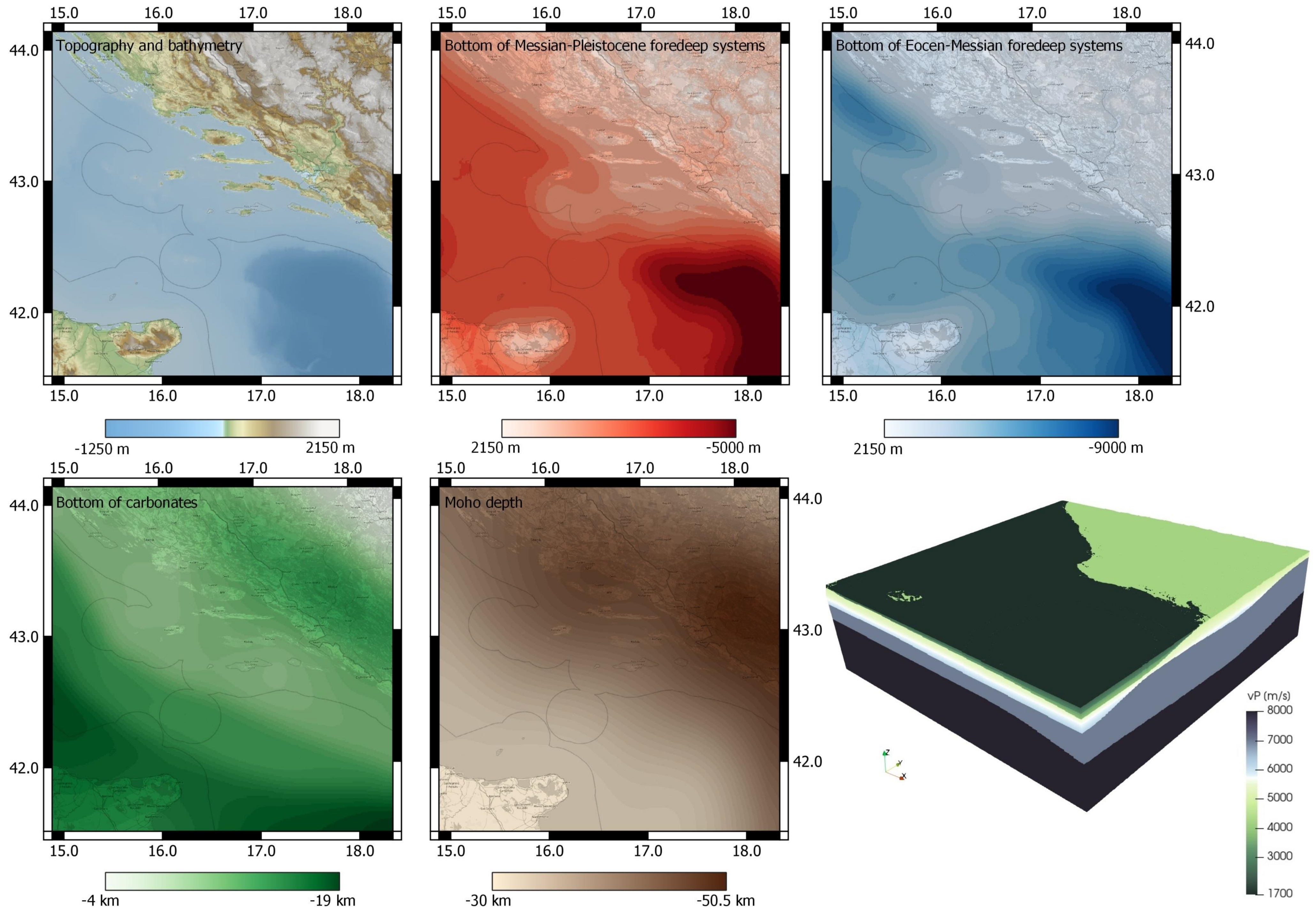

Fig. 3. New 3D structural model for the Central Adriatic Sea that covers 300 km × 300 km (41.525° - 44.092°N) × (14.882° - 18.331°E) area and extends to the depth of 80 km. The model describes seismologically relevant parameters, density, P- and S-wave velocity, on a working grid of 500 m in UTM (zone 33N) coordinate system. It includes surface topography, bathymetry and is represented by five layers: Messinian-Pleistocene foredeep systems, Eocene-Messinian foredeep systems, carbonates, lower crust and mantle.

RESULT VALIDATION

Besides visual inspection, in order to assess the reliability of LF simulations against the recorded data, we calculate the goodness of fit measure (GOF) following the work of [8]. We take the mean GOF score of all three seismogram components for peak ground velocity (PGV) and shaking duration. Although preliminary, results (Fig. 4.) show an improvement of the new 3D model against EPCrust, both in terms of duration and amplitude for the majority of the stations. Therefore, the next steps of our study are further refinement of the current model as well as running simulations using different source parametrizations.

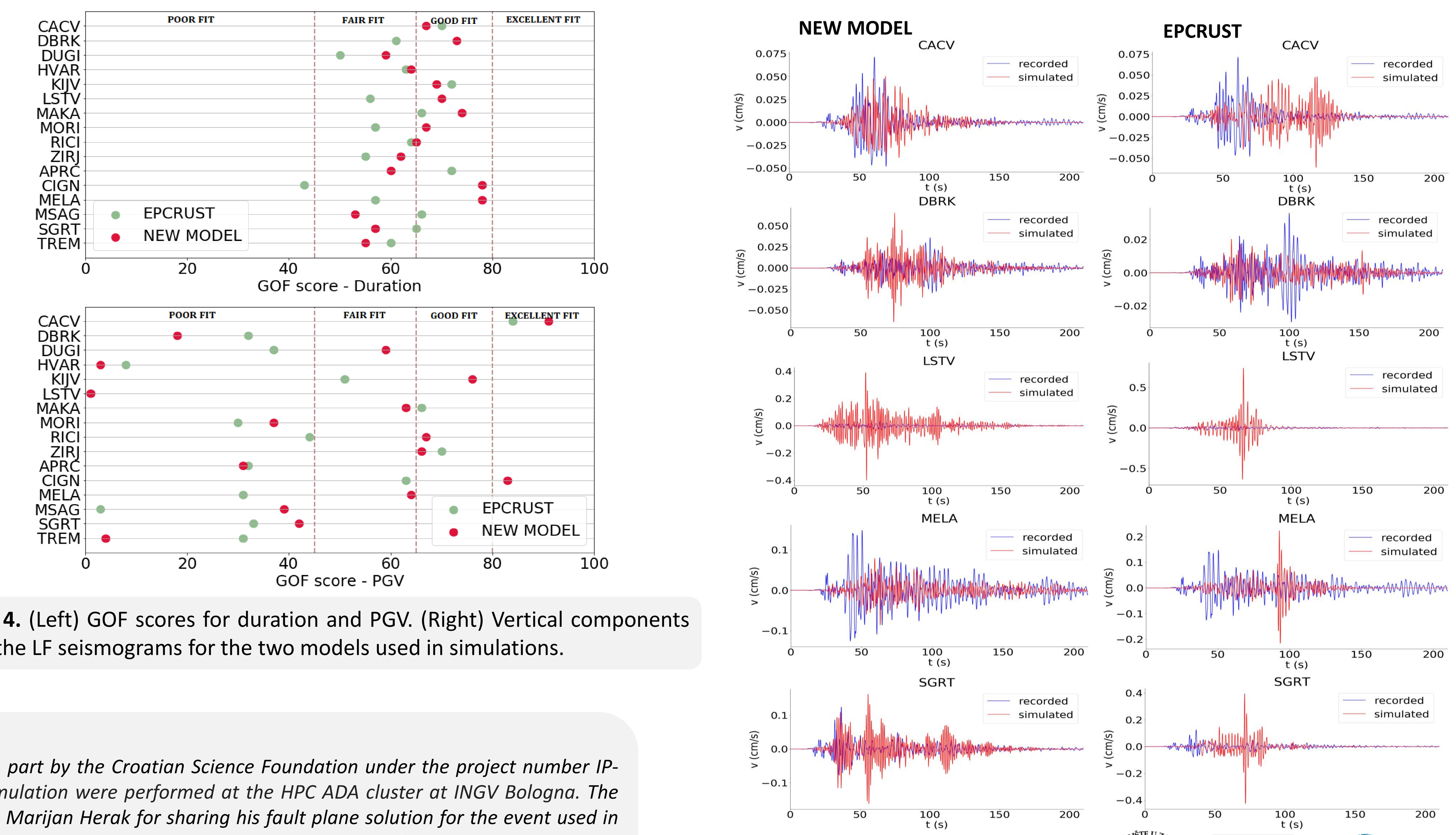

Fig. 4. (Left) GOF scores for duration and PGV. (Right) Vertical components for the LF seismograms for the two models used in simulations.

References

[1] Herak D, Herak M, Prelogović E, Markušić S, Markulin Ž (2005): Jabuka island (Central Adriatic Sea) earthquakes of 2003. Tectonophysics 398(3–4): 167-180. https://doi.org/10.1016/j.tecto.2005.01.007
[2] Herak M, Herak D, Markušić S (1996) Revision of the earthquake catalogue and seismicity of Croatia, 1908–1992. Terra Nova 8: 86–94.
[3] Molinari I, Morelli A (2011) EPcrust: A reference crustal model for the European plate. Geophysical Journal International 185: 352–364. https://doi.org/10.1111/j.1365-246X.2011.04940.x
[4] Fantoni R, Franciosi R (2010) Tectono-sedimentary setting of the Po Plain and Adriatic foreland. Rend. Fis. Acc. Lincei 21 (Suppl 1): 197–209. https://doi.org/10.1007/s12210-010-0102-4
[5] Zailac K, Matoš B, Vlahović I, Stipčević J. (2023). Referent seismic crustal model of the Dinarides, University of Zagreb. https://urn.nsk.hr/urn:nbn:hr:217:793485. Accessed 10 April 2023.
[6] Komatitsch D, Erlebacher G, Göddeke D, Michéa D (2010) High-Order Finite-Element Seismic Wave Propagation Modeling with MPI on a Large GPU Cluster. Journal of Computational Physics 229(20): 7692–7714. https://doi.org/10.1016/j.jcp.2010.06.024
[7] Olsen KB, Day SM, Bradley, CR (2003) Estimation of (Q) for Long-Period (>2 Sec) Waves in the Los Angeles Basin. Bulletin of the Seismological Society of America 93(2): 627–38.
[8] Olsen KB, Mayhew JE (2010) Goodness-of-fit criteria for broadband synthetic seismograms, with application to the 2008 mw 5.4 Chino Hills, California, Earthquake. Seismological Research Letters 81(5): 715–723.

Acknowledgements

This work has been supported in part by the Croatian Science Foundation under the project number IP-2020-02-3960. The numerical simulation were performed at the HPC ADA cluster at INGV Bologna. The authors would like to thank Prof. Marijan Herak for sharing his fault plane solution for the event used in simulation. The SPECFEM3D Cartesian wave propagation code is available at geodynamics.org/resources/specfem3dcartesian (accessed March 2023). The seismograms used in the study were recorded by seismological stations of the Croatian Seismograph Network (CSN) and Italian National Seismic Network (IV).