Towards a new era in seismological imaging of the lithosphere beneath the Pannonian Basin

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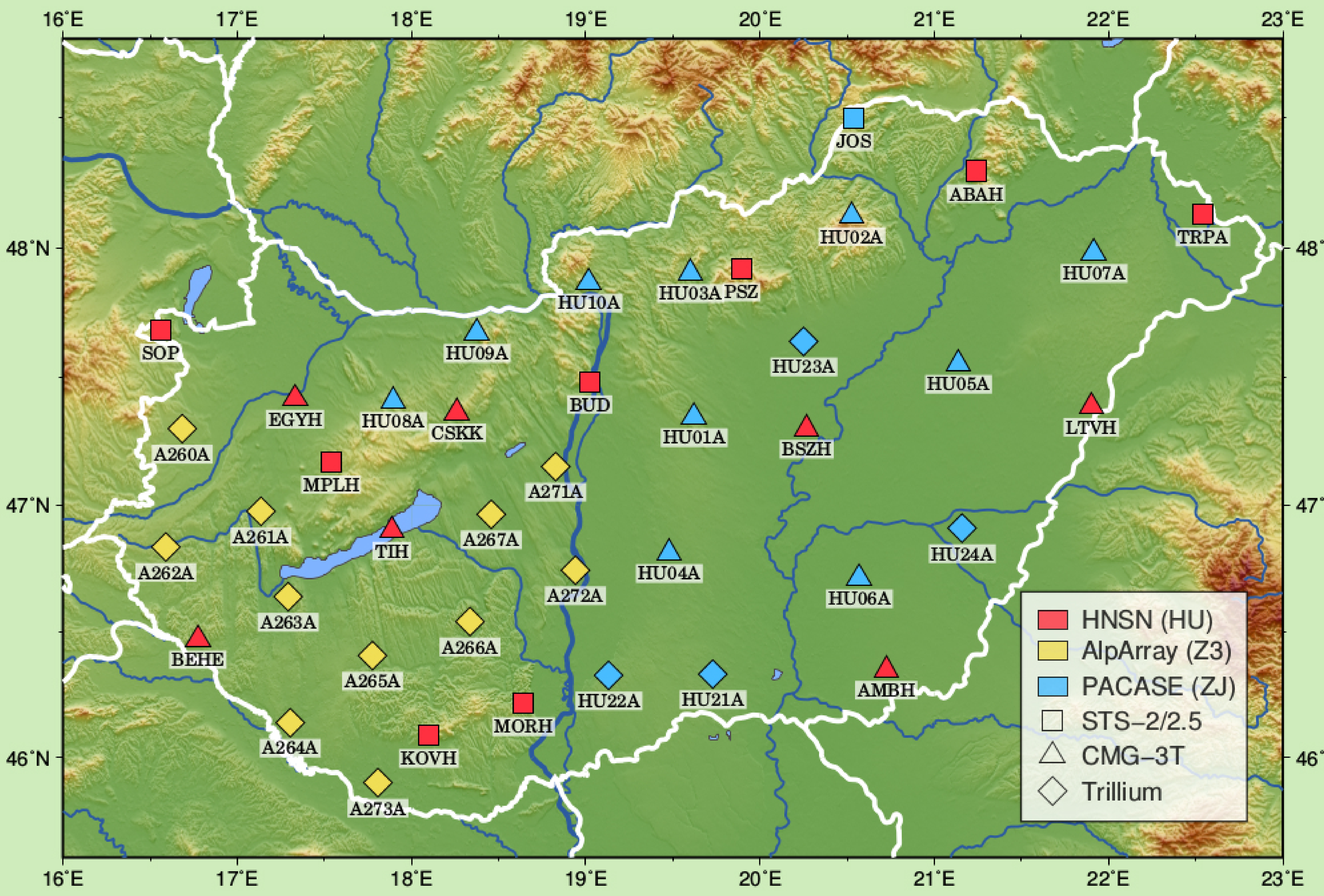
Introduction

Earthquake-generated elastic waves travel across the Earth's interior in all directions, so they are especially suitable for probing the subsurface for lithosphere structure. Detailed three-dimensional (3D) imaging of the lithosphere, however, requires a dense seismic network on the surface.

From July 2019, in cooperation with the German Seismological Broadband Array (DSEBRA) consortium, the Kövesligethy Radó Seismological Observatory (KRSO) operates 41 broadband seismic stations in Hungary. Hungary, and for that matter the Pannonian basin, has never been covered by such an unprecedentedly dense seismic network before.

The overall objective of these deployments is to provide the observational basis for high-resolution 3D imaging of the physical properties of the lithosphere and a more refined identification of discontinuities in and between the main tectonic microplates of the lithosphere and the underlying asthenosphere. The detailed images provided by this dense seismological network will vastly improve our understanding on the structure and geodynamics of the Carpathian-Pannonian region.

Network and Instrumentation



Fifteen permanent stations constitute the Hungarian National Seismological Network (HNSN) which is supplemented by eleven temporary deployments operating till the end of 2021. In addition, 15 temporary stations are equipped and financed by the German DSEBRA consortium and are to be operated till the end of 2020. Eleven temporary stations in Transdanubia belong to the AlpArray Seismic Network, whereas 15 temporary stations operate within the PAnnonian-Carpathian-Alpine Seismic Experiment (PACASE) project, which is a recently launched "AlpArray Complementary Experiment".

All the stations deployed in Hungary are equipped with high-quality broadband instrumentation that record the ground motion with 100 Hz sampling frequency. The data are collected by the Kövesligethy Radó Seismological Observatory and are archived at the ORFEUS EIDA node. The data of the temporary stations are available via the EIDA node for the participants of the AlpArray and PACASE projects, but they are not publicly available.

Case study

Station HU01A

(a) The sensor after orientation with magnetic compass and levelling

(b) For thermal insulation the sensor is covered with a pail filled with polystyrene packing foam peanuts.

(c) Digitizer/datalogger, battery and charger.

(d) The selected cellar. GPS antenna is mounted outside.

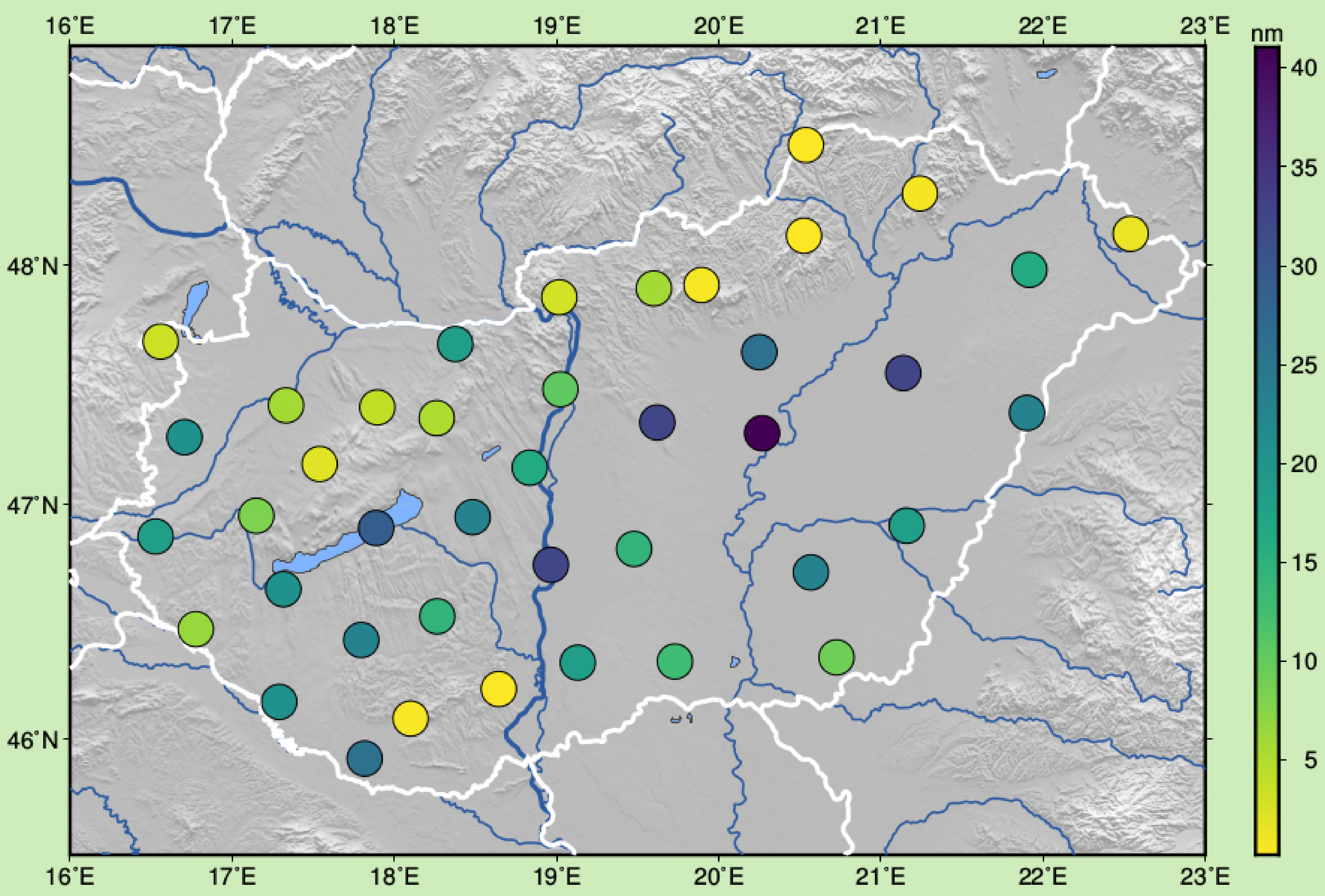

(a)


(b)

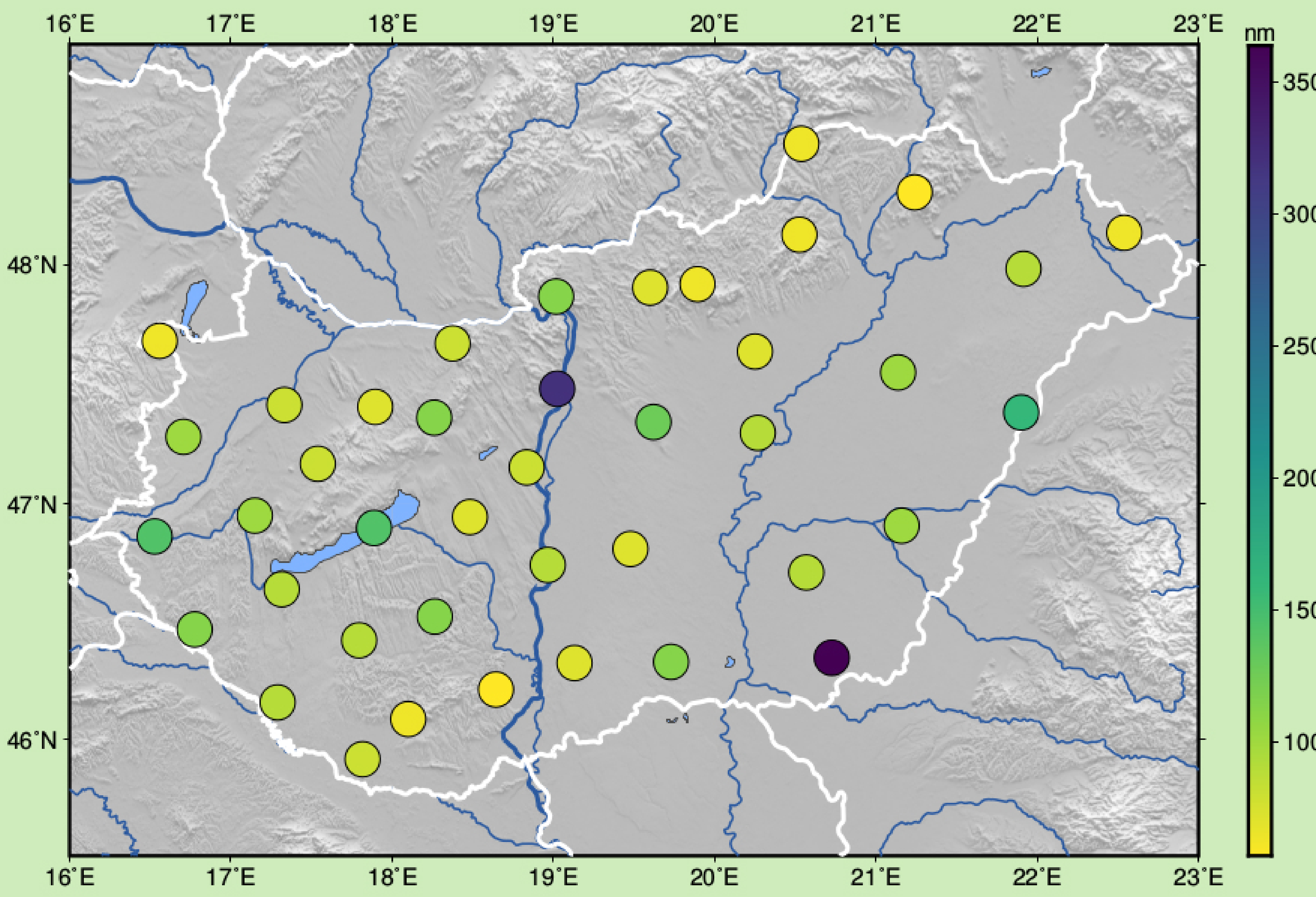

(c)


(d)

Noise characteristics



Maximum noise amplitude in nm at 5 Hz



Maximum noise amplitude in nm at 0.05 Hz

Noise levels at high frequencies are closely related to near-surface materials, such as loose deposits or well consolidated rocks. Therefore, high-frequency noise levels at deep sedimentary basins are usually high, which can be seen in the presented map (e.g. stations BSZH, HU05A). In comparison, noise levels at the stations located in the Hungarian mountain ranges are substantially lower.

On the other hand, noise levels at low frequencies are less sensitive to surface materials. As a result, we cannot observe any correlation with the geological environment for 0.05 Hz.

Detection capability

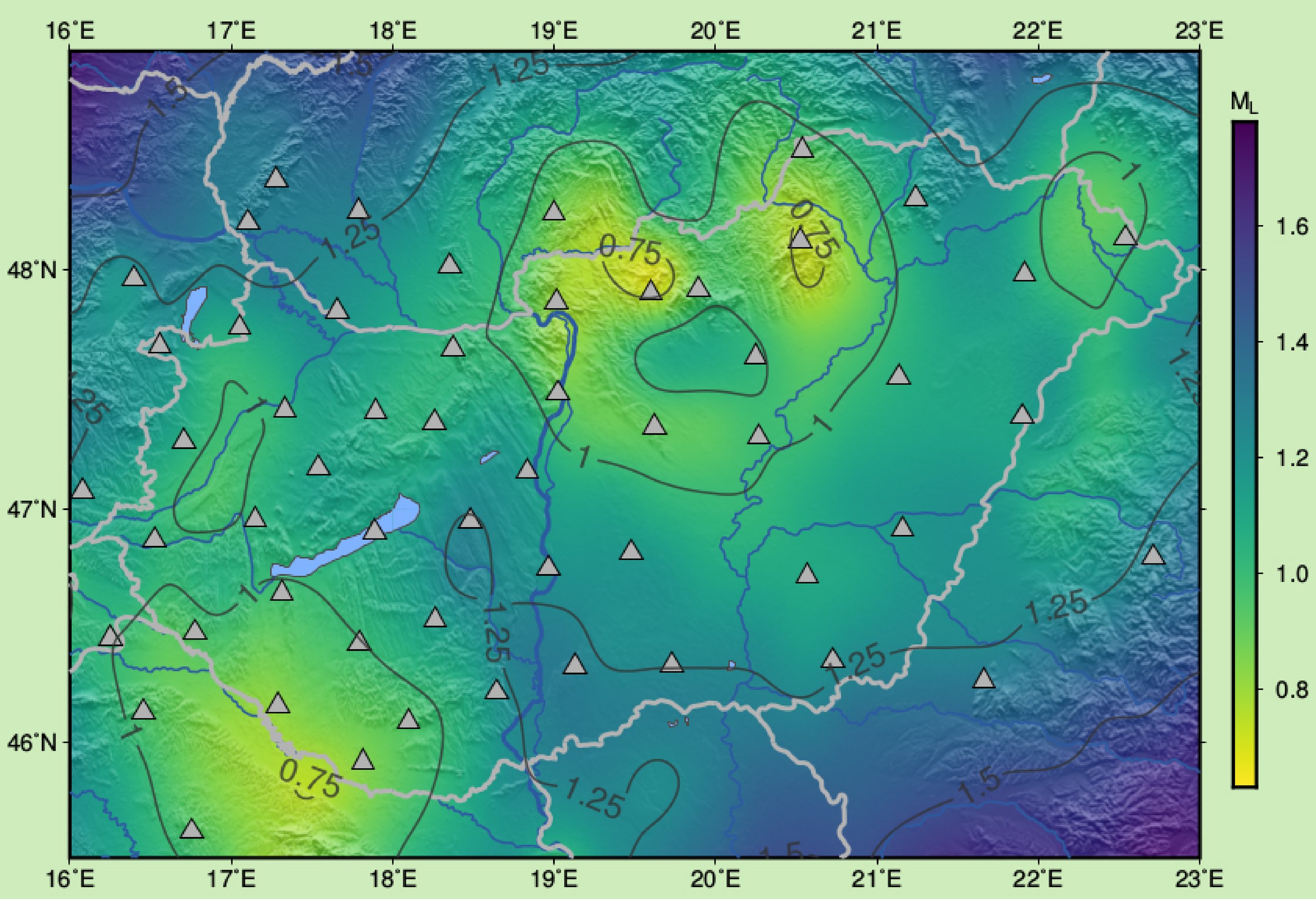
We have estimated the event detection capability of the network by using the SN-CAST method of Möllhoff et al., (2019). We have assumed that we could determine the magnitude of an earthquake, if at least 4 stations have recorded it with a maximum event amplitude at least 3 times of the background noise amplitude. As we do not rely solely on data from the Hungarian stations to localize seismic events, data from the neighboring countries were also considered.

Since the event detection capability of the seismic network highly depends on the background noise level, we have estimated the maximum background noise displacement at 5 Hz based on power spectrum densities. The 90 percentile was chosen to calculate for worst-case scenario. As noise levels differ significantly during day and night, we have constructed two maps showing the varying detection capabilities of the network. Detection capability of the network is sufficient to identify earthquakes above $M_L = 1.25$ in Hungary regardless of time of day. It is even possible to detect $M_L = 0.5$ events in northern Hungary at night.

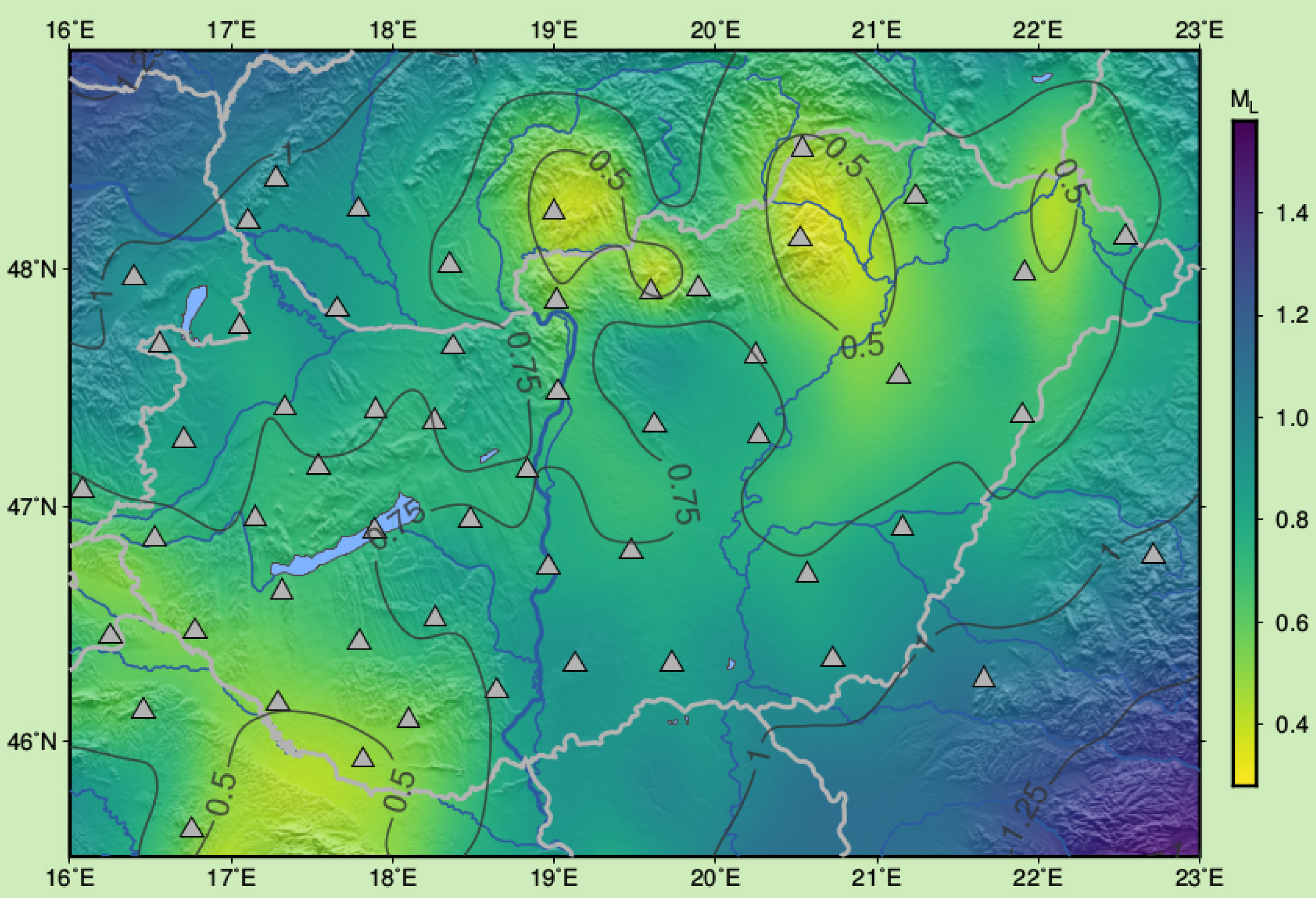
Waveforms of local seismic events are dominated by high-frequency components, while teleseismic earthquake signals have much longer characteristic periods. Noise level at high frequencies in the sedimentary basins is elevated, therefore these stations are not capable of detecting small ($M_L < 1.0$ in daytime and $M_L < 0.75$ at night) local events. However, the spatial distribution of low-frequency noise amplitudes is much more uniform across the country allowing us to record teleseismic events with good signal-to-noise ratio even in deep sedimentary basins.

Reference

Möllhoff, M., Bean, C. J., Baptie, B. J. (2019). SN-CAST: seismic network capability assessment software tool for regional networks-examples from Ireland. *Journal of Seismology*, 23(3), 493-504.



Detection capabilities during daytime (8 a.m. – 4 p.m.)



Detection capabilities at night (10 p.m. – 6 a.m.)

Acknowledgement

Three ongoing research projects supported by the National Research, Development and Innovation Fund (NRDI) and the Hungarian Academy of Sciences (HAS) contribute to and benefit from the large amount of high-quality data produced by the described seismic network:

- A thematic research project (Grant No.**NRDI K124241**) whose aim is to create detailed 3D P- and S-wave velocity images of the crust and upper mantle beneath the Pannonian basin and to map the topography of the Moho and the lithosphere-asthenosphere boundary (LAB).
- A National Excellence Programme (Grant No. **NRDI 2018-1.2.1-NKP-2018-00007**) which is about to develop and evaluate a novel seismotectonic hazard map of Hungary.
- The MTA CSFK Lendület Pannon LitH$_2$Oscope grant (Grant No. **LP2019-5/2019**) which aims to develop a novel petrophyscial model for the lithosphere-asthenoshpere boundary ("pargasosphere" concept). This concept has several empirically testable predictions on the behaviour of seismic waves at the LAB, and the Carpathian-Pannonian Region offers a unique natural laboratory for this globally relevant experiment.

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MOMENTUM OF INNOVATION