SEISMIC TOMOGRAPHY OF MACEDONIA

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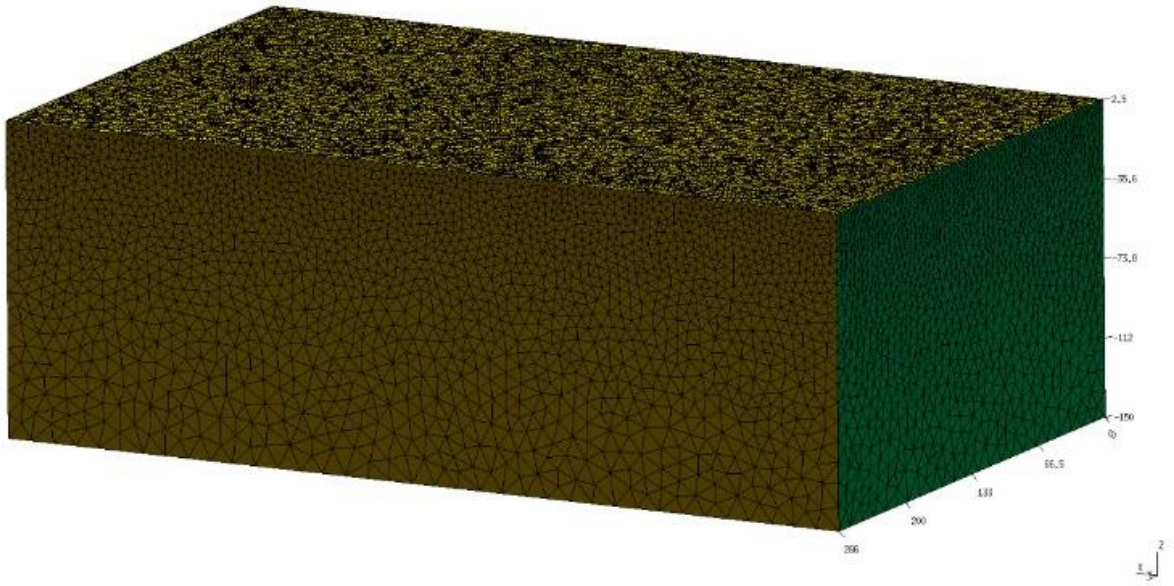
ABSTRACT

A novel geotomography technique has been applied in and around Macedonia using selected earthquakes that occurred over a period of 40 years and were recorded on 47 seismograph stations. The aim was to test this new tomography method for the first time in investigation of the crustal shape and structures in that specific tectonic environment with an extensive dataset.

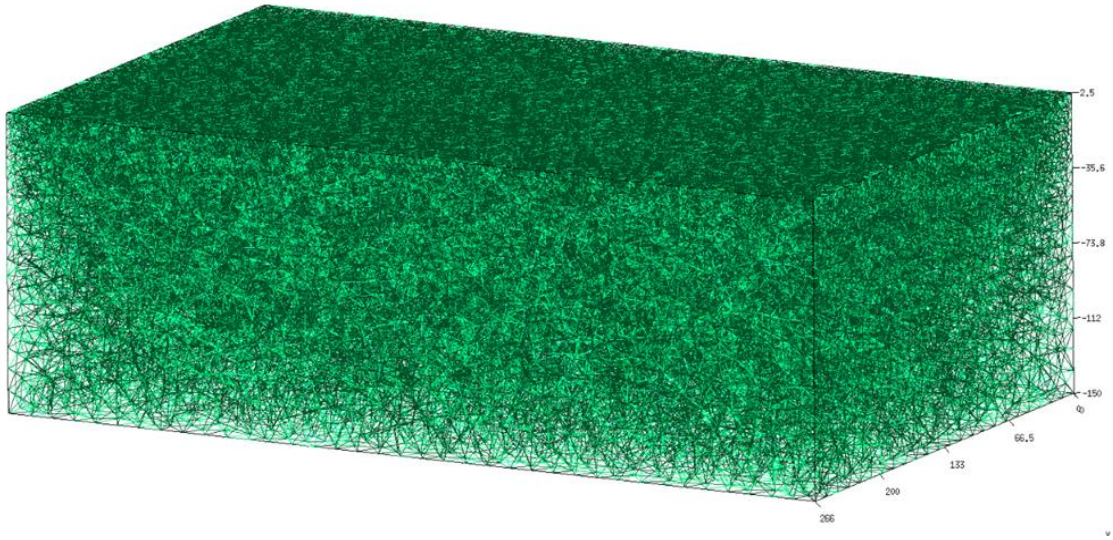
A three-dimensional velocity model and many cross-sections of the crust were produced by this methodology and compared with the previous models of Macedonia. They show the potential of the tomography application in revealing geological features on local and regional scale.

The new images will contribute towards a better understanding of the seismicity and tectonics in that part of the Balkans and assist in the process of integrated seismic hazard assessment.

This tomographic inversion is performed using irregular grid parametrization. A tetrahedron cell discretization of complex geological models is especially useful in situations of rough topography and high-contrast anomalies. This experimental work is on-going and the computer code is being tested in different tectonic environments.



a)



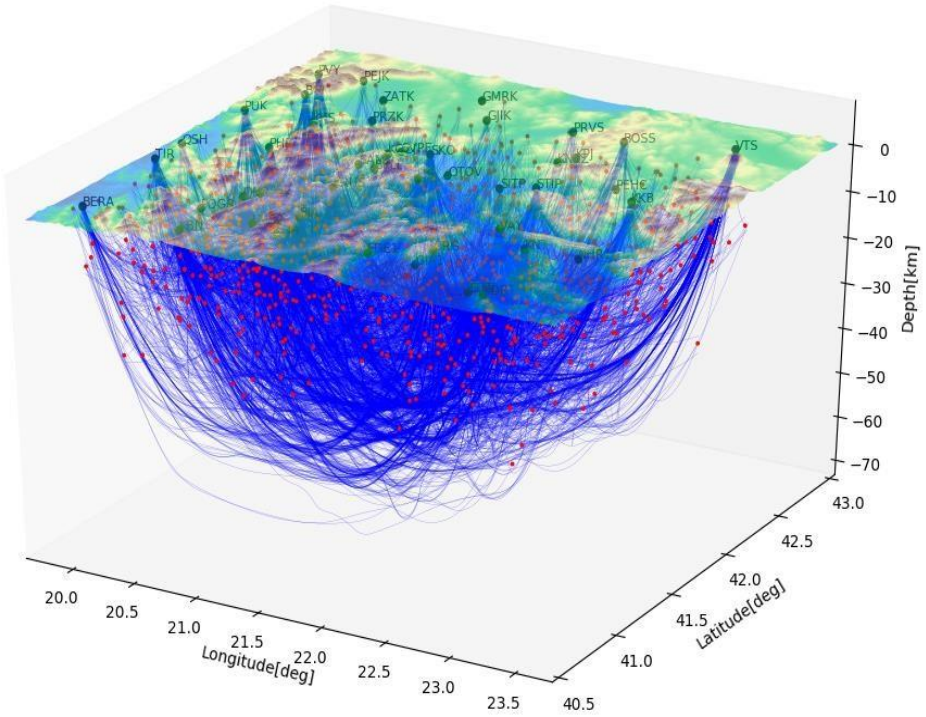
b)

Schematic representation of a) parametrization and b) tetrahedron ribs used for ray tracing.

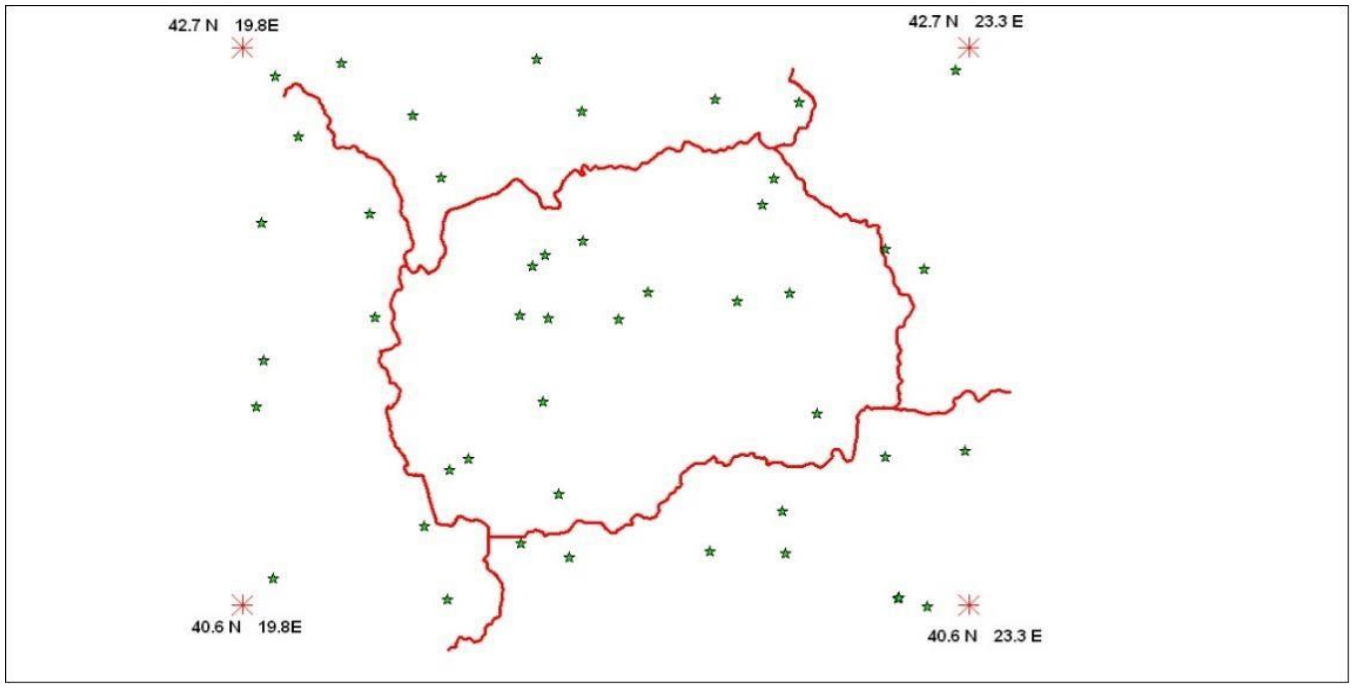
Selected earthquakes that occurred over a period of 40 years recorded on 47 seismic stations across the region of Macedonia in South Eastern Europe, were used. The new geotomography software was applied to invert regional P and S travel times from around 780 chosen earthquakes recorded on those stations. More than 7000 P-arrivals and equivalent number of S-arrival times were used in the tomographic analysis. The events that occurred in a cuboid of 19.5E to 23.5E degrees and 40.5N and 43N degrees and down to 60km deep were processed. The volume was discretised into cells of 17.5kmx17.5km at the surface and depth ranges in the intervals of 5, 10, 15, 20, 30, and 45 to 60km.

Table 1: Velocity model used for the Macedonian region.

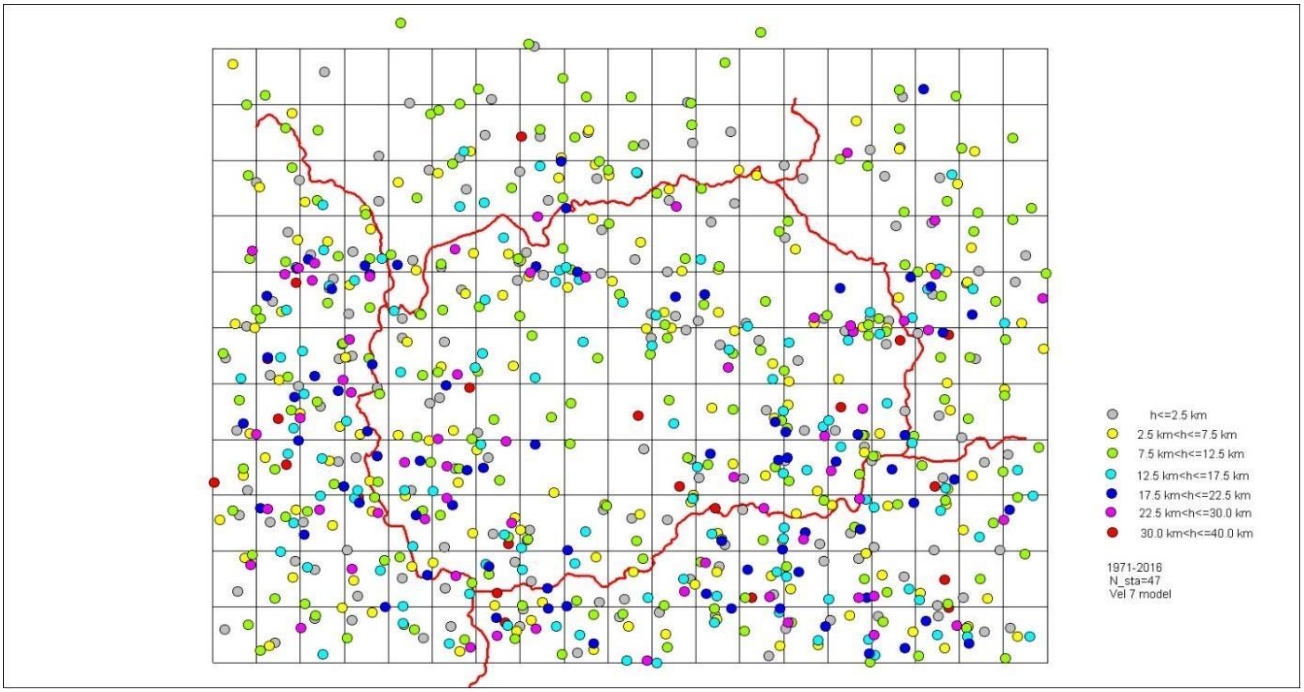
Depth (km)	Vp (km/s)	Vs (km/s)
0-5	4.4	2.54
5-10	5.1	2.95
10-15	6.2	3.58
15-20	6.5	3.76
20-30	6.9	3.99
30-45	7.7	4.45



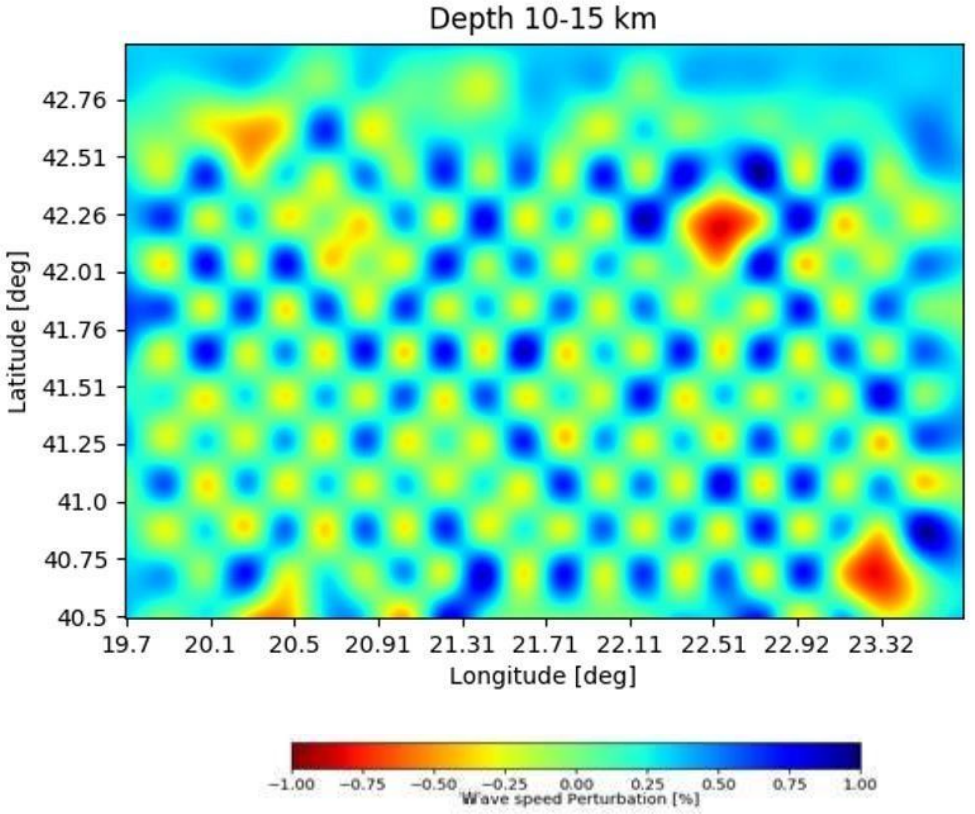
The ray paths and the coverage for the earthquake foci and the surface seismograph stations over the topography of Macedonia (earthquakes-red stars, stations-black triangles, ray paths-blue lines).

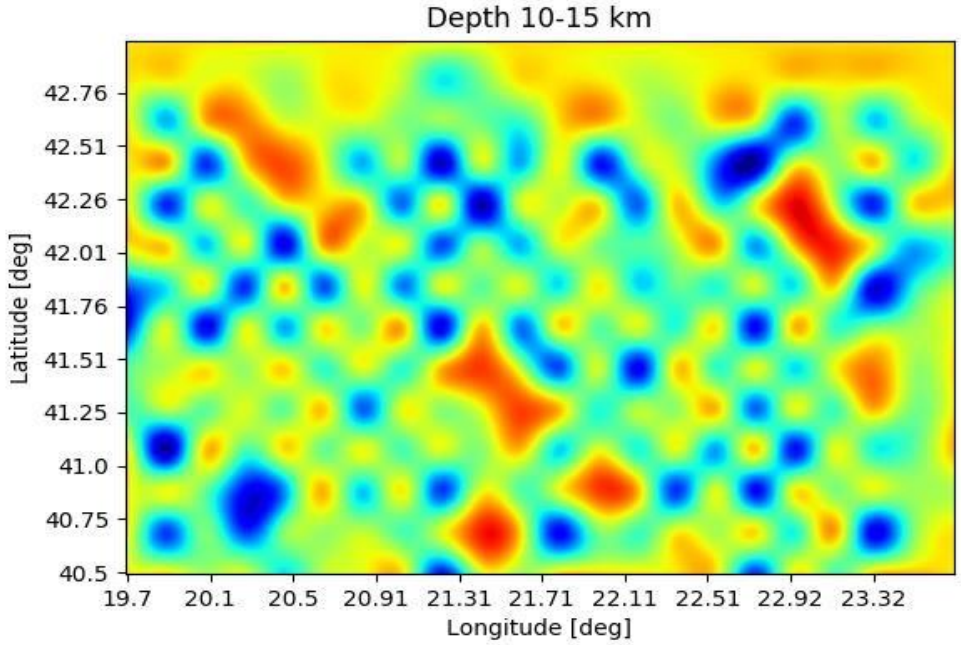


The location of the 47 selected seismic stations used in the experiment.

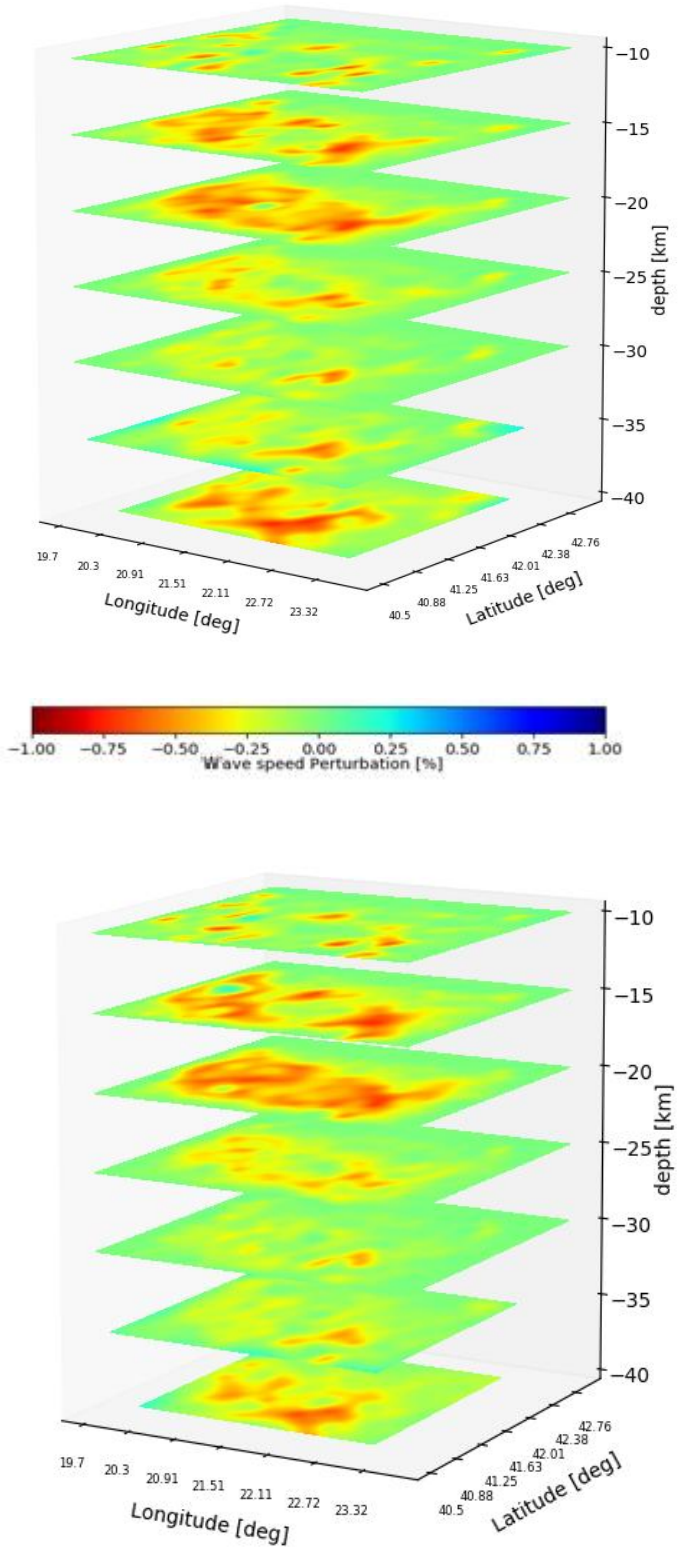


The location of the chosen seismic events (circle colours represent depth).

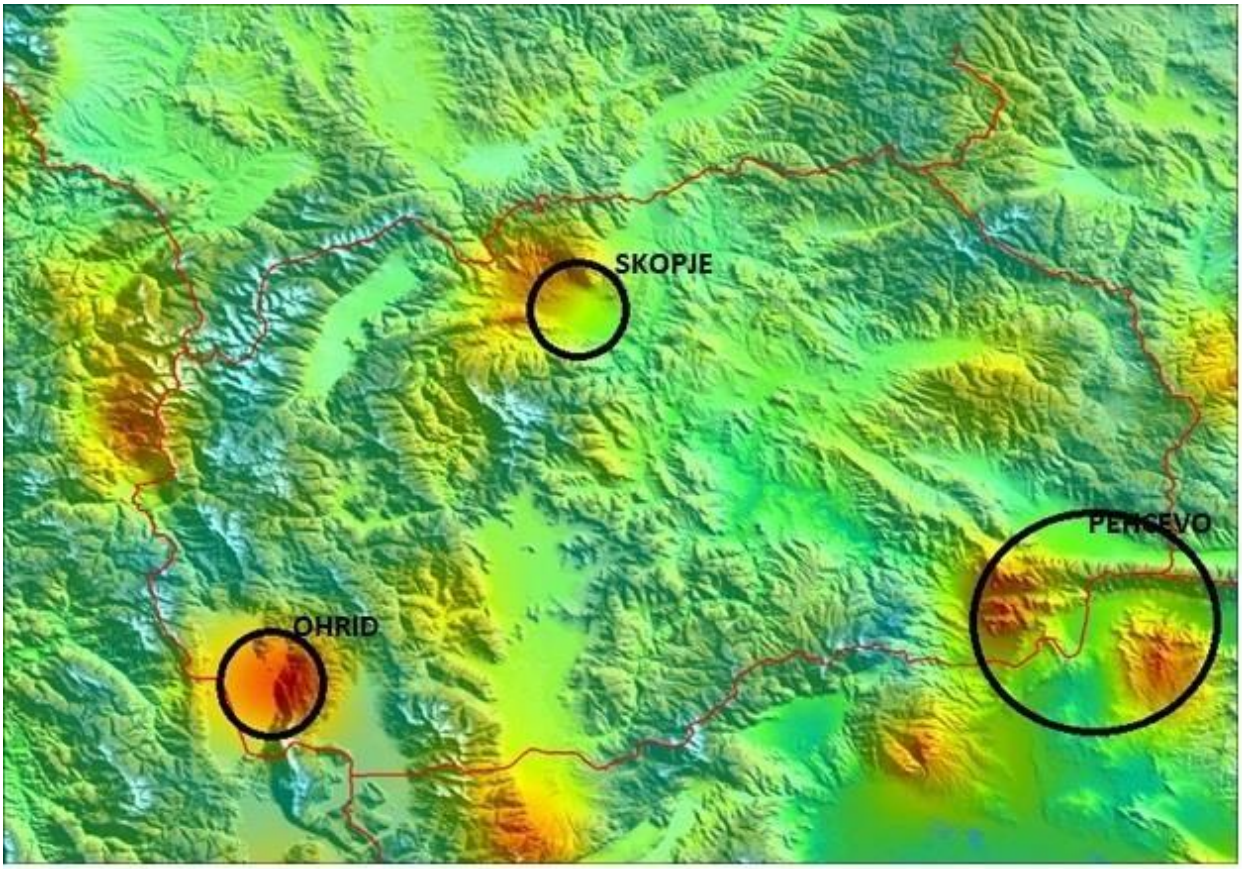




Examples of the checkerboard tests P-wave (top) and S-wave (bottom) for the layer between 10 and 15 km.



Horizontal P-wave (top) and S-wave (bottom) slowness perturbation images at depths.

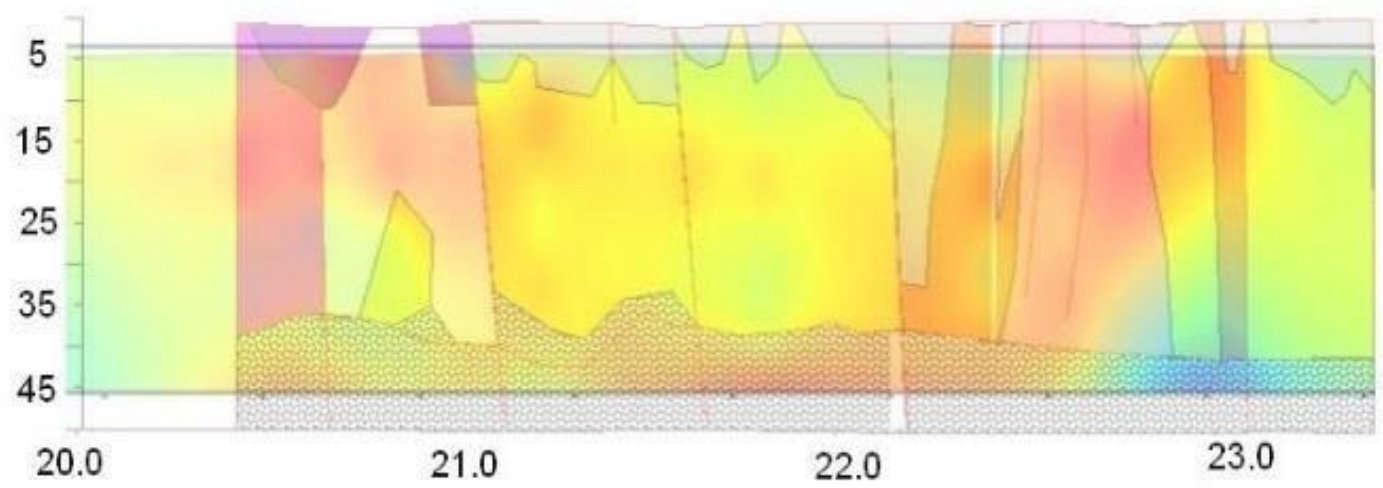


Combined horizontal P-wave slowness perturbation image at 0-5 km and topography of Macedonia. Circles indicate three seismic zones where the strongest and most damaging earthquakes occurred in the last century (Skopje 1963 – magnitude M6.1, Ohrid 1911 – magnitude M6.7 and Pehcevo 1904 – magnitude M7.8).

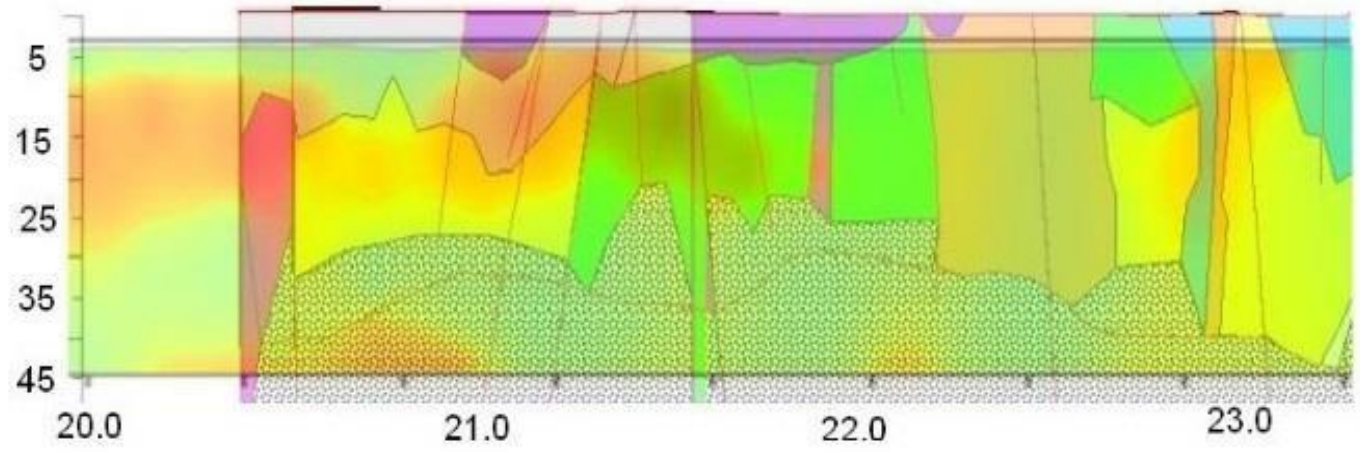
In order to interpret the results with the geology, the horizontal tomographic images of the first layer were superimposed on the topography map.

The tomography results in the vertical slices through the cuboid along selected latitudes and longitudes can reveal more details of the lithosphere under specific regions. For instance, we show the latitudinal slices near 41^{o}N and 42^{o}N and the superimposed seismic profile extending E-W across Macedonia where large-scale experiments were made in the 1980's with the seismic method known as Deep Seismic Sounding (DSS).

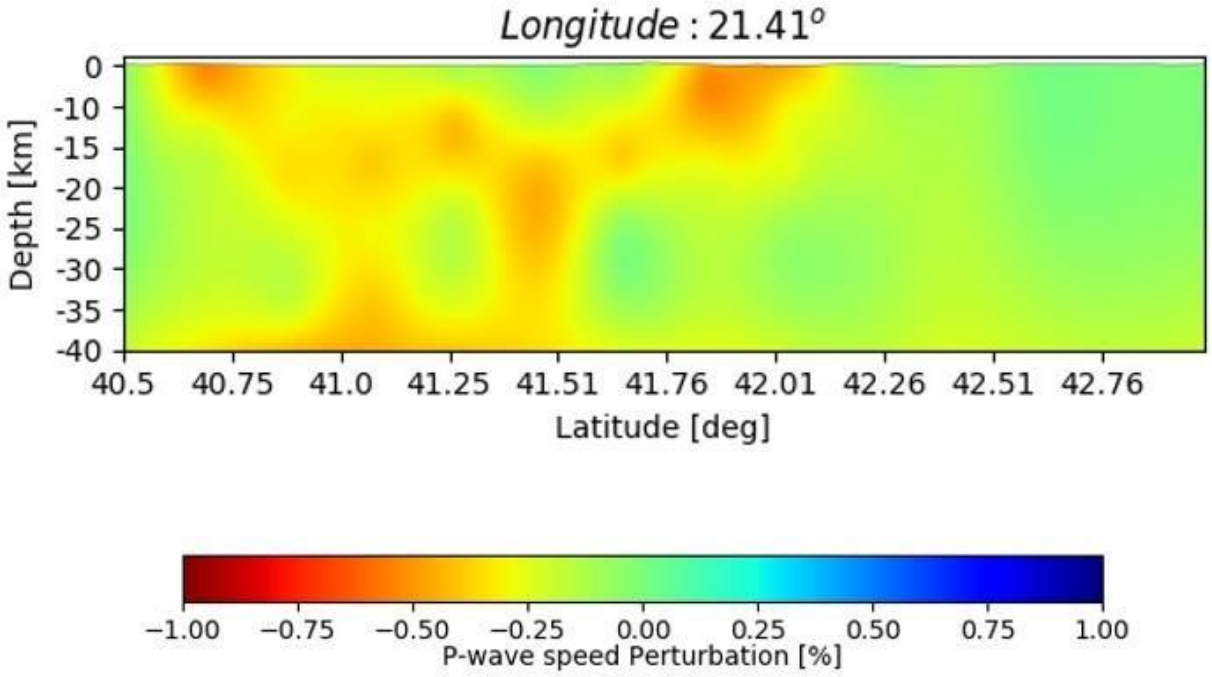
The vertical slices through the cuboid at various angles can assist in identifying localized stress regimes in Macedonia, as well as an estimate of Moho discontinuity. For example, the longitudinal cross-sections through 21.41^{o}E show strong lateral variations underneath Skopje area.

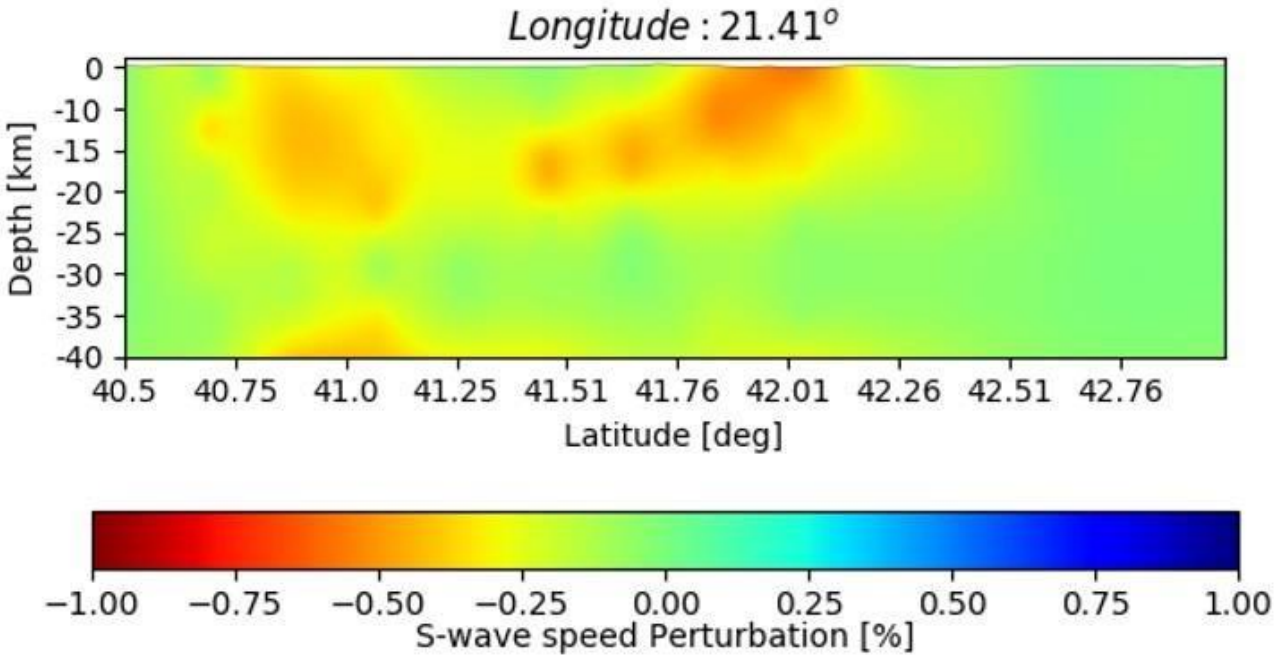


Combined seismic profile and the slowness perturbation image for the vertical latitudinal slice near 41^{o}N.



Combined seismic profile and the slowness perturbation image for the vertical latitudinal slice near 42^{o}N.





P and S-slowness perturbation images for the vertical longitudinal slice near 21.41^{o}E.

SUMMARY

The tomographic study of Macedonia is an on-going work and the authors hope to continue in more details with a modified application. 3-D variations to the velocity model will be further explored with extended datasets and new zone parametrization. The main aim here was to test the possibilities of geotomography for investigation of the crustal shape and structures in active tectonic regions with the latest available data.

Those interpretations are in close agreement with the map of Moho discontinuity in the central part of the Balkan Peninsula obtained by applying geostatistical procedures. Also, the Moho depths are in proximity to the values produced by receiver function methods.

The 3-D models and cross-sections of the crust produced by this new methodology show the potential of the geotomography application in revealing velocity perturbation on both local and regional scale. The new images can contribute towards better understanding of the seismicity and tectonics in the Balkan region and improvement of the earthquake hazard assessments.

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