Lithospheric thickness under the Dinarides

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Introduction and motivation

Interaction between Adriatic microplate and stable Europe played a crucial role in the tectonic development of Western and Central Mediterranean. There are many papers about northern and western margin of Adria but relatively few about eastern, e.g. about collision of Adria and Europe in the Dinarides.

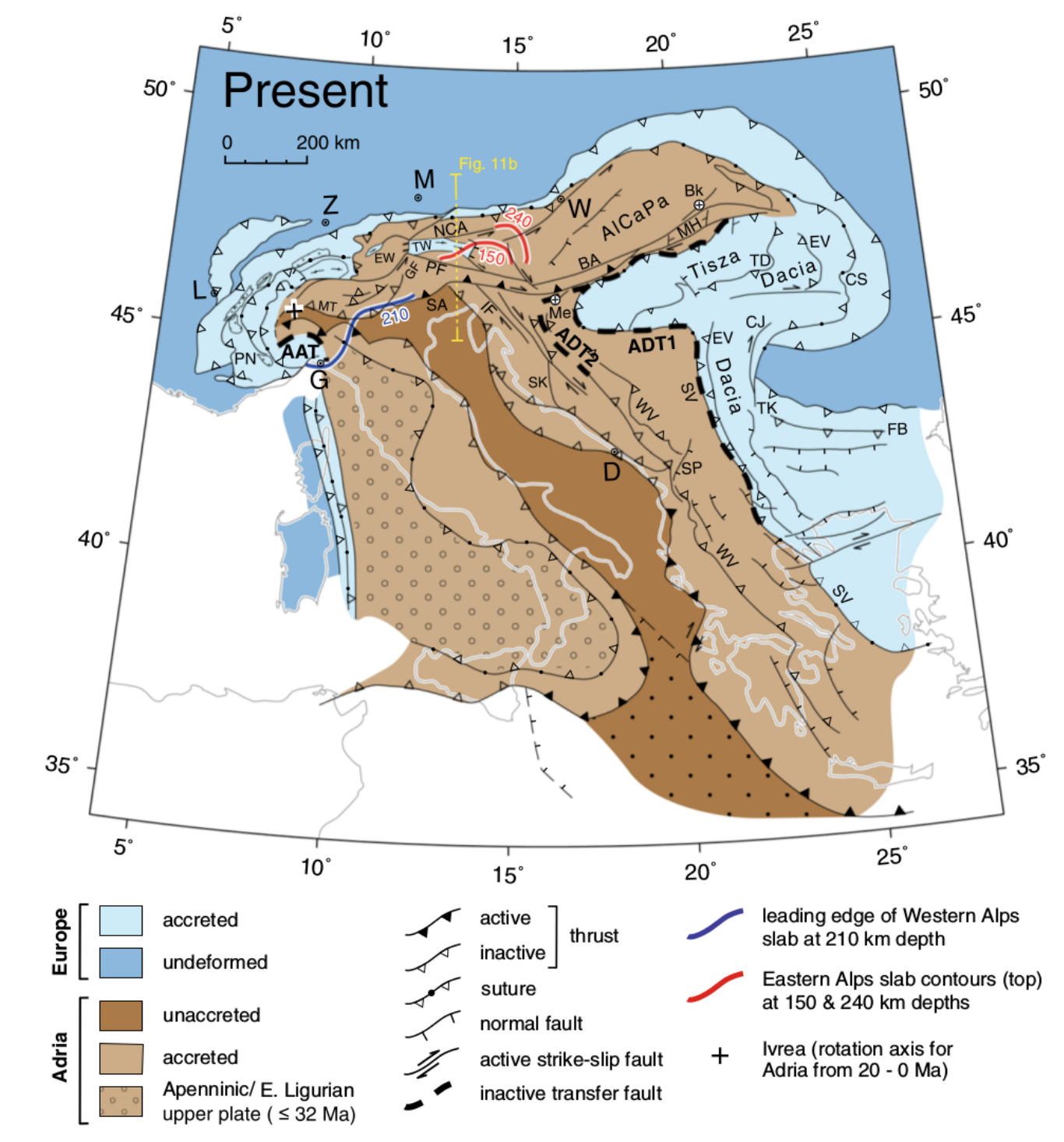

Figure 1. Tectonic map of the Alps, Apennines, Carpathians and Dinarides showing main faults, tectonic units, and surface traces of slabs beneath the Alps (taken from Handy et al. 2014).

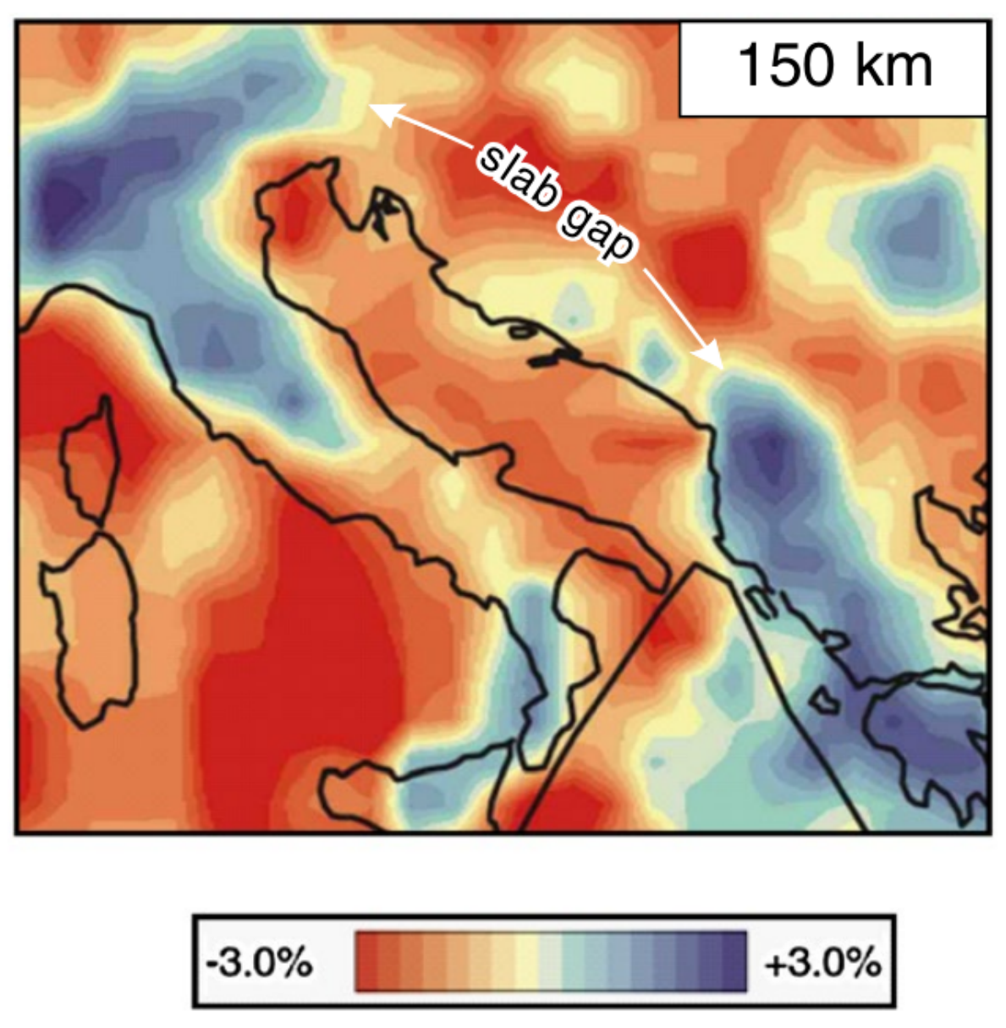

Figure 2. Tomographic map at 150 km depth showing low velocity zone in the NW Dinarides. This low velocity zone has been interpreted as the "slab gap" beneath the Dinarides (taken from Handy et al. 2014).

The crustal thickness and lithospheric structure under the Dinarides are poorly resolved and dominated by large seismic transition zones that are not obviously linked to the tectonic structures observed at the surface. Previous investigations mapped two strong reflectors, one shallow, which was interpreted as the boundary between sedimentary cover and crystalline basement and significantly deeper one ascribed to Mohorovičić discontinuity. Results indicate a relatively narrow belt of thicker crust (>40km) following the main axis of the Dinarides and thinning rapidly towards Pannonian basin and Adriatic sea.

As with the crustal structure, little is known about the deeper structure of the Dinaric collision zone. Seismic tomography indicates an inclined high-velocity zone down to a depth of around 160 km beneath the central-south Dinarides (Bijwaard and Spakman, 2000). This anomaly has been interpreted as subducted Adriatic lithosphere that is located west of the presumed Adria-Eurasia plate boundary that is marked by an oceanic suture zone (Ustaszewski et al., 2010). Interestingly, all tomographic models of the area show an unusual feature, a large low-velocity anomaly beneath the northern Dinarides that separates the afore mentioned slab anomaly in the South Dinarides from the slab anomaly beneath the Eastern Alps.

To explain this "slab gap" some authors suggested that the slab was thermally eroded due to opening of the Panonnian basin and influx of asthenospheric material (Ustaszewski et al., 2008, Handy et al., 2014}. This idea was expanded to incorporate slab tearing beneath Dinarides and subsequent rise of the asthenosphere as the crucial mechanism in the explanation of the slab gap (Handy et al., 2014). Recently, it has been suggested that at least part of the extension in the south-eastern Pannonian basin and Internal Dinarides is caused by the lithospheric delamination under the Dinarides. Delamination may have progressed further into the External Dinarides and this would have profound influence on how we see the geodynamical process in the area.

Here we show preliminary results of the receiver function investigation using the data from the Croatian Seismological Network. Most of the stations are located in External Dinarides close to the Adriatic coast with several stations located further inland. We calculated P and S receiver functions in order to map crustal and lithospheric thickness.

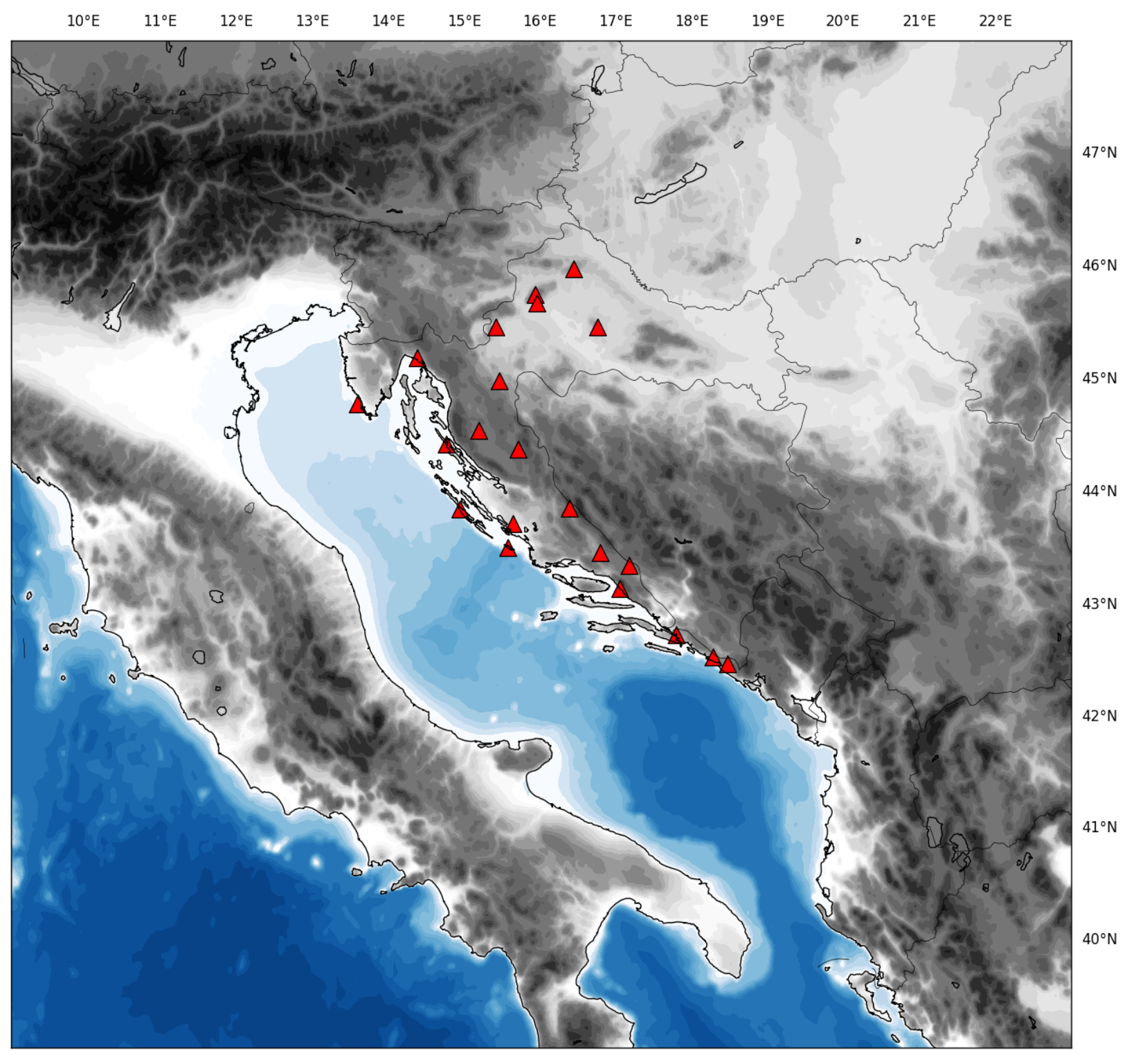

Figure 3. Map of seismic stations used in this study (red triangles) overlaid on the topography map.

P and S Receiver Functions

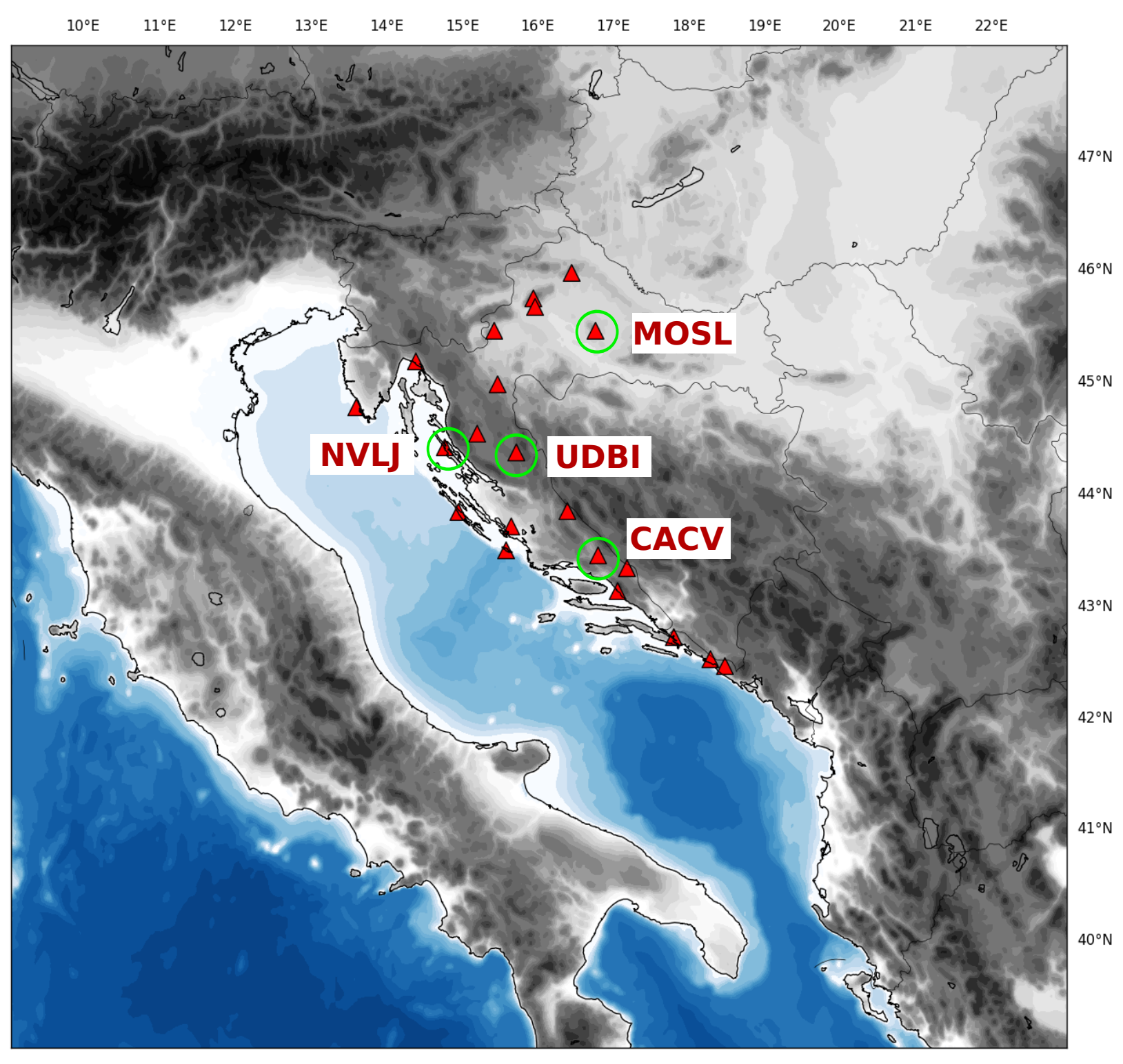

Figure 4. Map of seismic stations used in this study (red triangles) overlaid on the topography map. Green circles mark the stations whos P and S receiver functions are shown in Figure 5. These four stations are representative of different regimes in the wider area around the Dinarides.

Receiver functions technique with teleseismic events is very suitable for studying the crust and upper mantle structure beneath stations, thus becoming one of the standard tools for such study. The principle of receiver functions is to separate the converted Ps or Sp phases generated at the discontinuities beneath stations in the case that the direct P or S is a delta function. In this work we use coordinate transform technique for the separation of Ps or Sp waves, the deconvolution algorithm to extract P and S receiver functions and stacking technique to improve the signal quality.

The great advantage of the S receiver function technique is that ringing due to mainly crustal multiples is clearly separated from the direct conversions. In contrast to the often very complicated P receiver functions, fewer signals are usually visible in good quality S and SKS receiver function data. On the other hand P receiver function contain higher frequency information thus enabling us to map the velocity transitions more accurately.

We base our preliminary results on the qualitative analysis of the P and S receiver functions (PRF and SRF). By using the velocity model from previous studies (see Stipčević et al., 2011 and references therein) we calculated depth to two most prominent features seen in the calculated receiver functions. On most of the stations we have observed strong positive Ps phases from the Moho and found a good agreement with the previous depth estimations. Furthermore, preliminary results from Sp phases show presence of a discontinuity in the upper mantle which we associated with the transition of lithosphere to asthenospere (LAB).

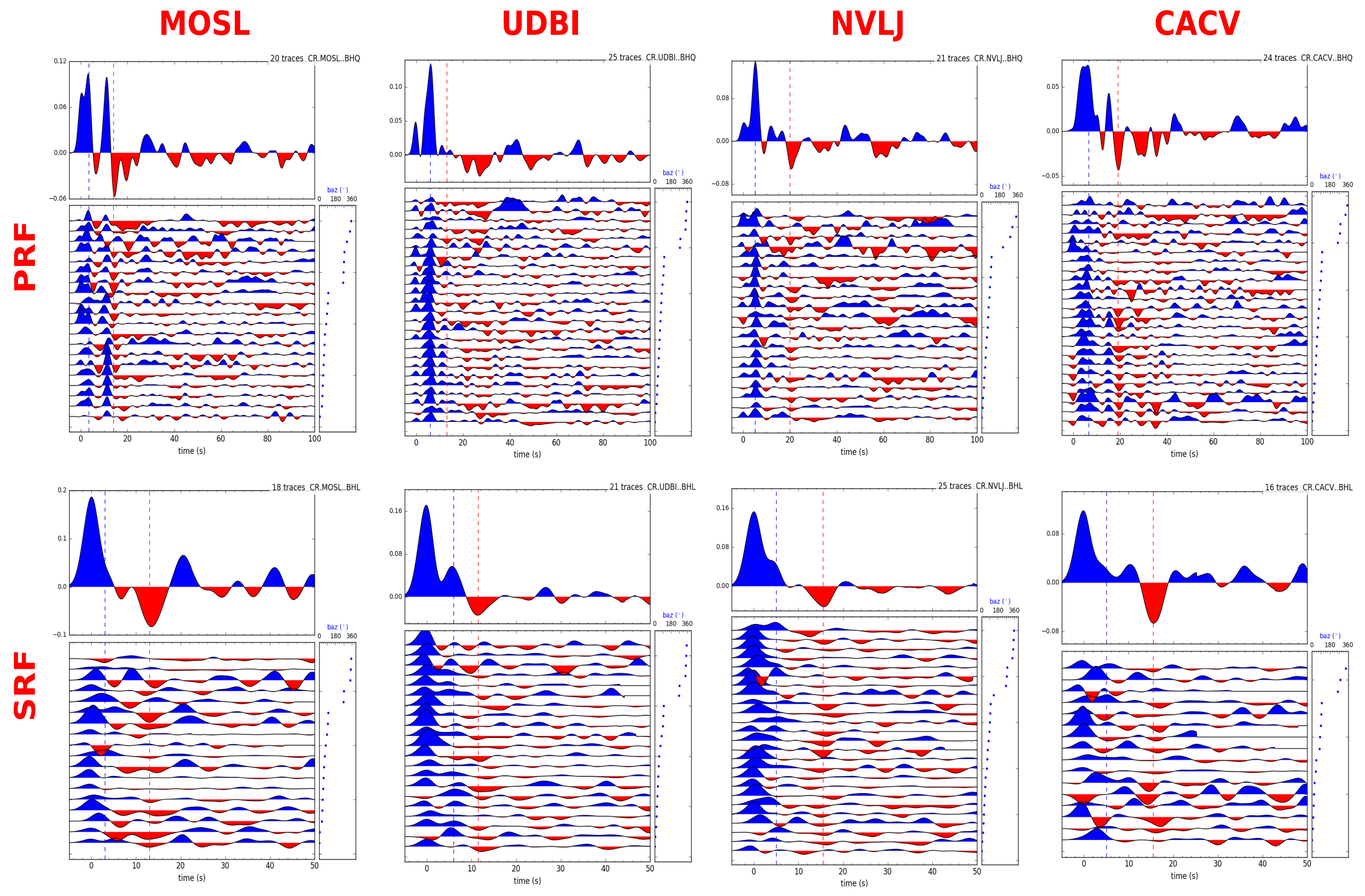

Figure 5. An example of P and S receiver functions at four stations marked in Figure 4. Traces are rotated, deconvolved, moveout corrected and summed. Moho (dotted blue line) is visible in both upper and lower panels. A negative converted phase marked with red line is visible only in the lower panels. This phase interpreted here as lithospheric-asthenospheric boundary (LAB) is generated in the upper mantle by a low velocity zone at a varying depth between 70 and 130 km at most stations used here. Usually this phase is not visible in the P receiver functions because it is obscured by the Moho reflection multiples.

Crustal and Lithospheric Thickness

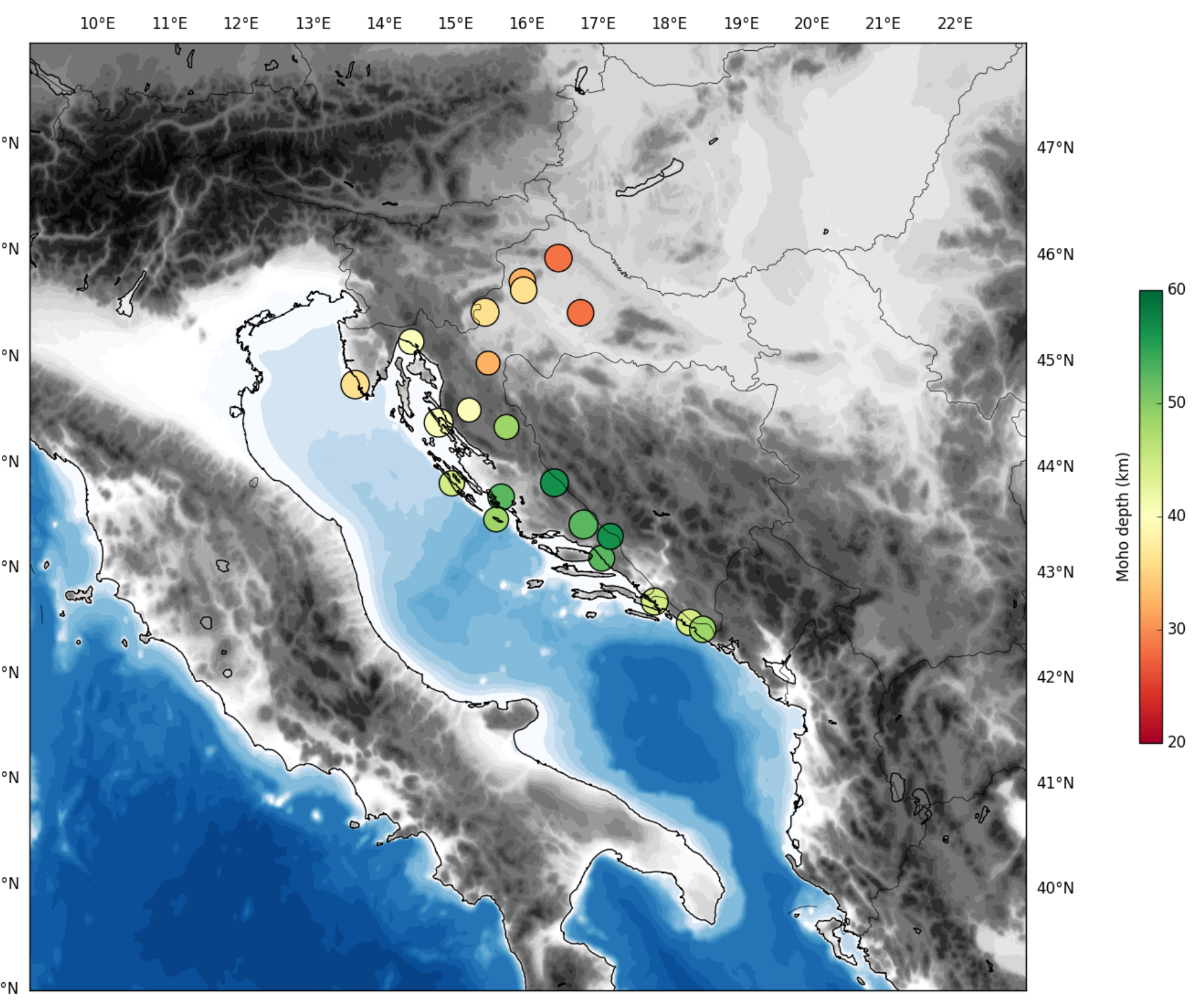

Figure 6. Corresponding map of the crustal thickness calculated at Croatian Seismological Network stations from P receiver functions. Greens indicate thicker crust (>45 km) while reds indicate thinner crust (<30km).

In the Dinarides, teleseismic events recorded at a dense network of permanent seismic stations have been exploited to create receiver functions. Both PRFs and SRFs show a coherent phases that gives consistent results for the lithospheric structure. The converted phases are due to a sharp velocity increase for Moho and decrease for LAB that occurs at variable depth across the study region.

The discontinuities are deepest beneath the central Dinarides (55-60 km for Moho and 120–140 km for LAB). The Moho depths follow previously established pattern with thicker crust under the main axis of the Dinarides and thinning towards Pannonian basin and Adriatic sea (Figure 6). On the other hand distribution of the deeper discontinuity (LAB) shows more complex pattern (Figure 7). We see that LAB is shallowest under the Northern Dinarides (>90 km) in the area where tomographic images mapped low velocity zone. Furthermore, in the southwestern edge of the Pannonian basin where we expected smallest lithospheric thickness we mapped depths of over 100 km.

In our preliminary analysis we link this lithospheric thickness distribution to the mantle upwelling due to the opening of the Pannonian basin. Similarly to the previous work (Ustaszewski et al., 2008) we believe that the thinner LAB in the Central Dinarides may be caused by the thermal erosion due the mantle upwelling. On the other hand higher LAB thickness in the SW Pannonian basin indicates that there may be other explanations for the low velocity anomaly under Central Dinarides, such as possible subduction rollback (delamination) or breaking of the subducting plate. In order to confirm these hypothesis more work needs to be done, possibly using more stations available in the area and utilizing different approaches to probe upper mantle.

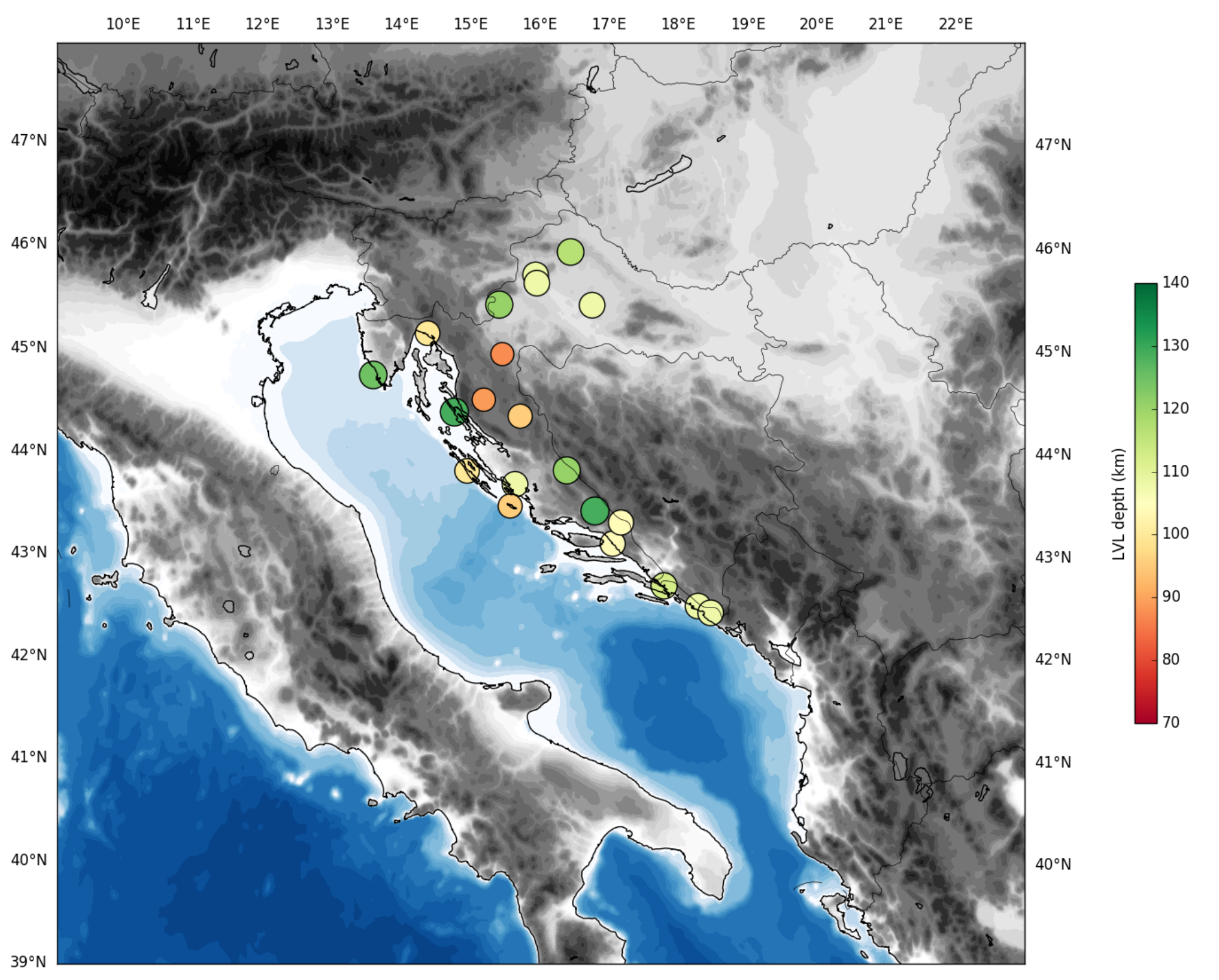

Figure 7. Corresponding map of the lithosphere-asthenosphere boundary calculated at Croatian Seismological Network stations from S receiver functions. Greens indicate thicker lithosphere (>110 km) while reds indicate thinner lithosphere (<90km).

Conclusion and Future Work

Measurements from all stations show good quality. In the next step we plan to utilize more stations located in the wider Dinarides area. We hope that these results can shed some light on how the geodynamical processes in the region influenced the evolution of the area influenced by Adriatic microplate.

Acknowledgments

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