Anisotropic upper mantle structure of the Eastern Alps

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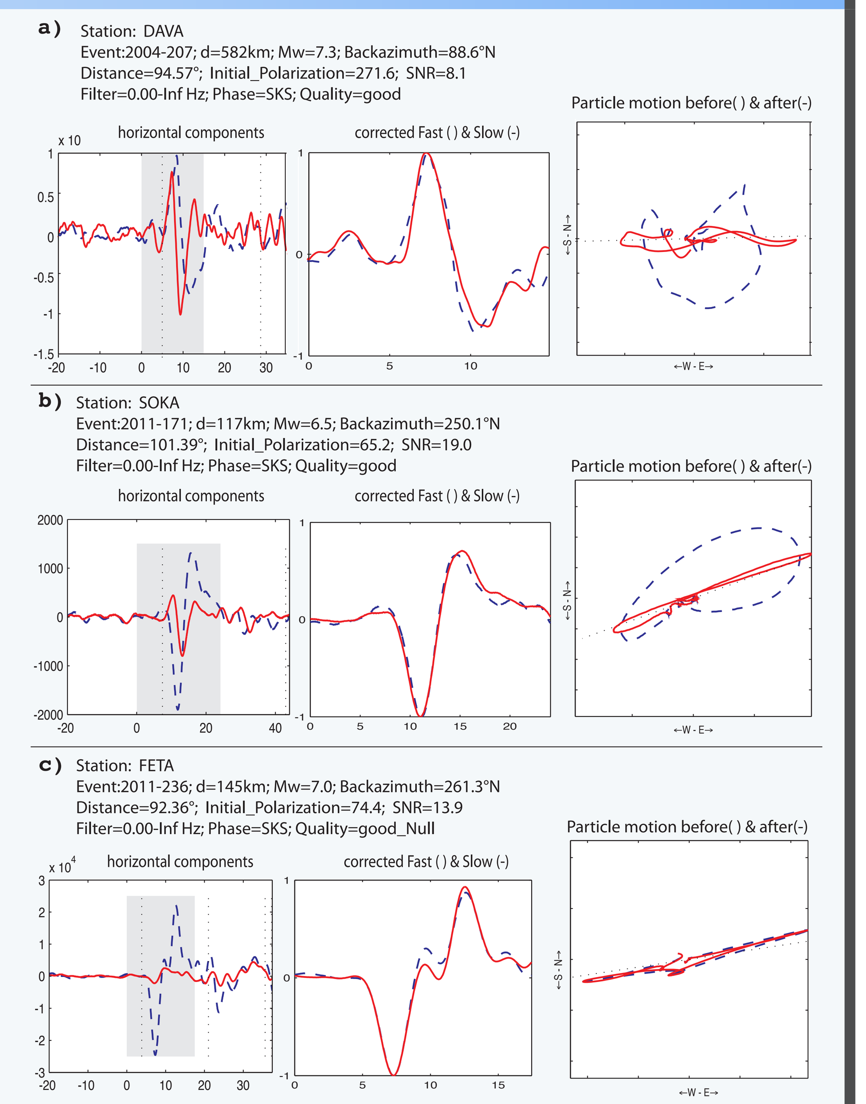
Overview

Mountains chains at the Earth's surface result from deformation processes within the Earth. Such deformation processes can be observed by seismic anisotropy. The shear waves can record large-scale anisotropy produced by lattice-preferred orientations (LPO) of rock-forming minerals, particularly of olivine. In this study, we investigate upper mantle anisotropy beneath the Eastern Alps by measuring the splitting of teleseismic SKS/SKKS phases.

Method and Data

The nature of anisotropic structures is characterized by the shear wave splitting method. Two splitting parameters are defined: the fast orientation azimuth (ϕ, angle between fast axis and radial direction) and the arrival delay time between the fast and slow polarization (δt). We used the transverse energy minimization technique (SC) [1] to recover the splitting parameters by utilizing the SplitLab package [2]. One example of splitting parameters measurement by the SC technique is illustrated in this Figure. The data set comprised the teleseismic events occurred at epicentral distance range 90° to 130° and magnitudes greater than 6 Mw for the time period between 2002 and 2013, recorded by the Austrian broadband seismological network (OE); Seismic network of Slovenia (SL); Italian seismic network (IV), NE-Italy broadband network (NI), and Sudtirol network (SI). All together data from 33 stations were used.



Tectonic background

Surface geology and tectonic evolution of the Alps appear rather complex [3], and it may be enlightening to study mantle structure in the region. Tomographic images show velocity anomalies that can be interpreted in the context of suture zones and the major subduction events [4, 5]. At the eastern end of the mountain chain, the Alps have been connected in the geological past with the Carpathians and the Dinarides. Nowadays, one important tectonic feature of the area is the extrusion of the central part of the Alps towards the Pannonian basin to the East as proposed by earlier studies (e.g., [6]).

References

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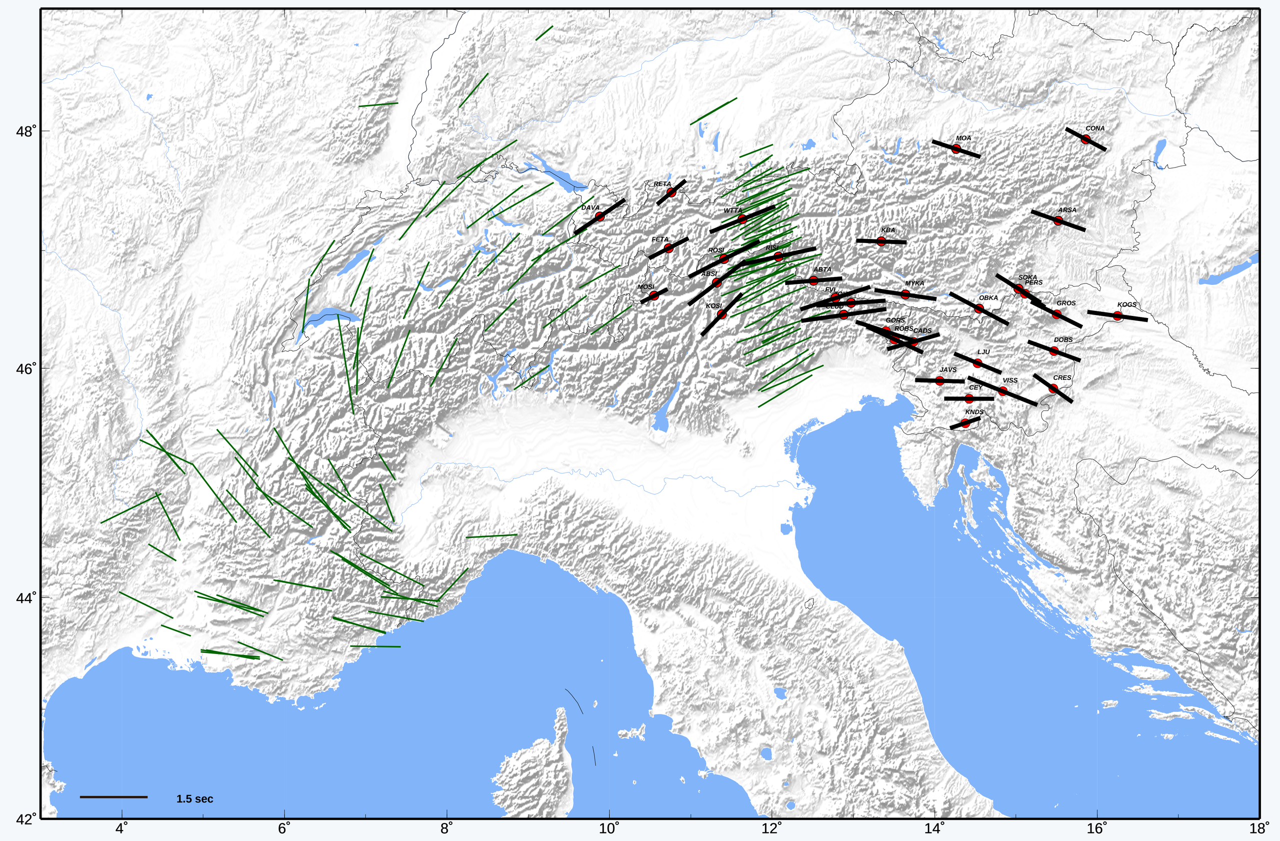
Shear wave splitting measurements

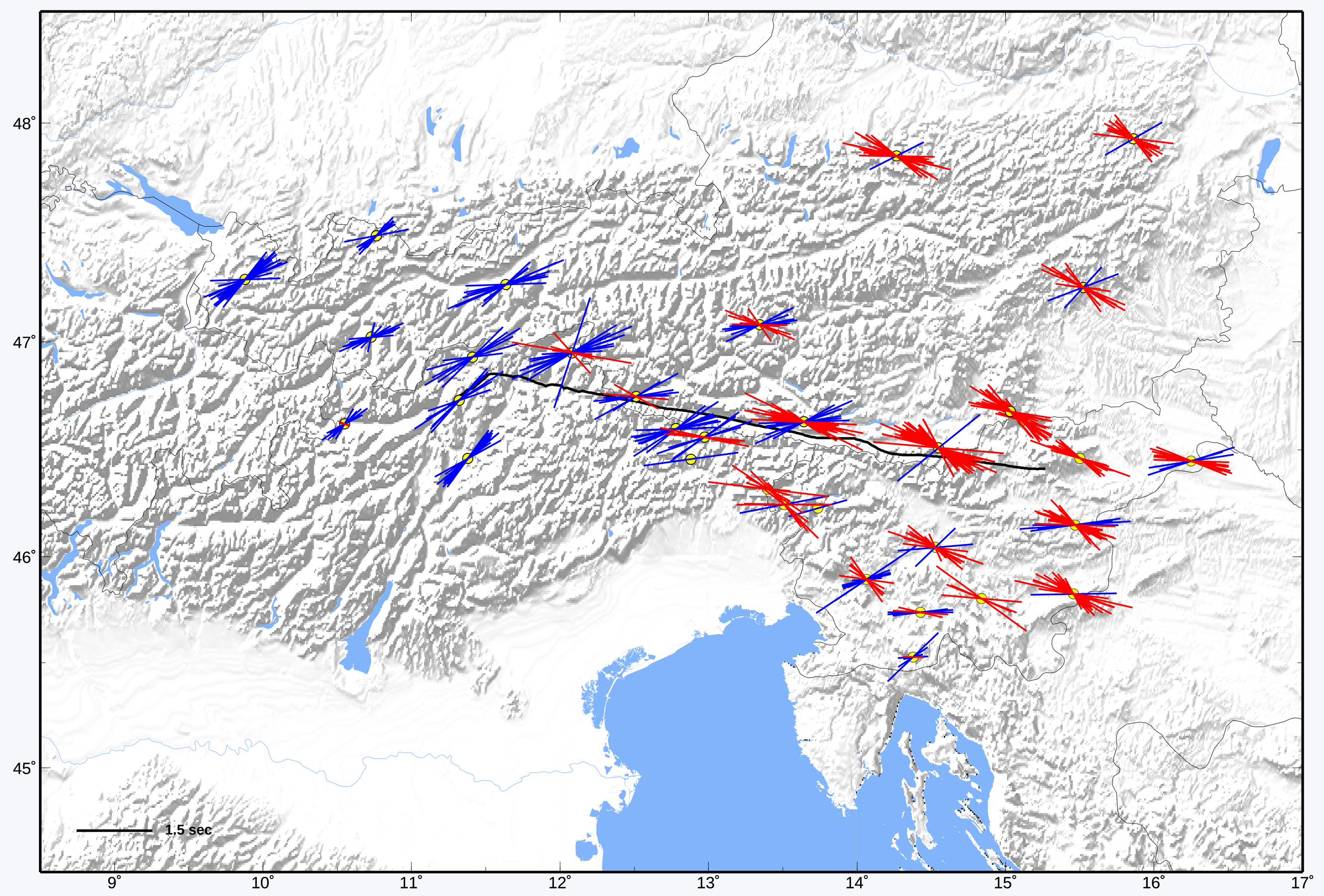
The average values for each station (calculated over the good quality measurements) are summarized in this Figure together with the results of previous studies for the Western Alps [7] and the central Alps [8] (green vectors). The orientation of fast azimuths, ϕ, is presented by vectors where vector length corresponds to the mean value of delay times (δt) for each station. The fast orientations measured from stations located in the central Alps (in longitude range of 9° E and 12° E) are in good agreement with the results of former studies. These directions turn gradually to nearly East-West, and further to the east they turn to predominantly fast azimuth of N115°.



In a previous study, [9] we described the mountain chain parallel anisotropy pattern in the upper mantle under the Alps. The results of 21 further stations are added in addition to the 12 stations used in that study. They also clearly show the rotating pattern of fast orientation along the Alps.

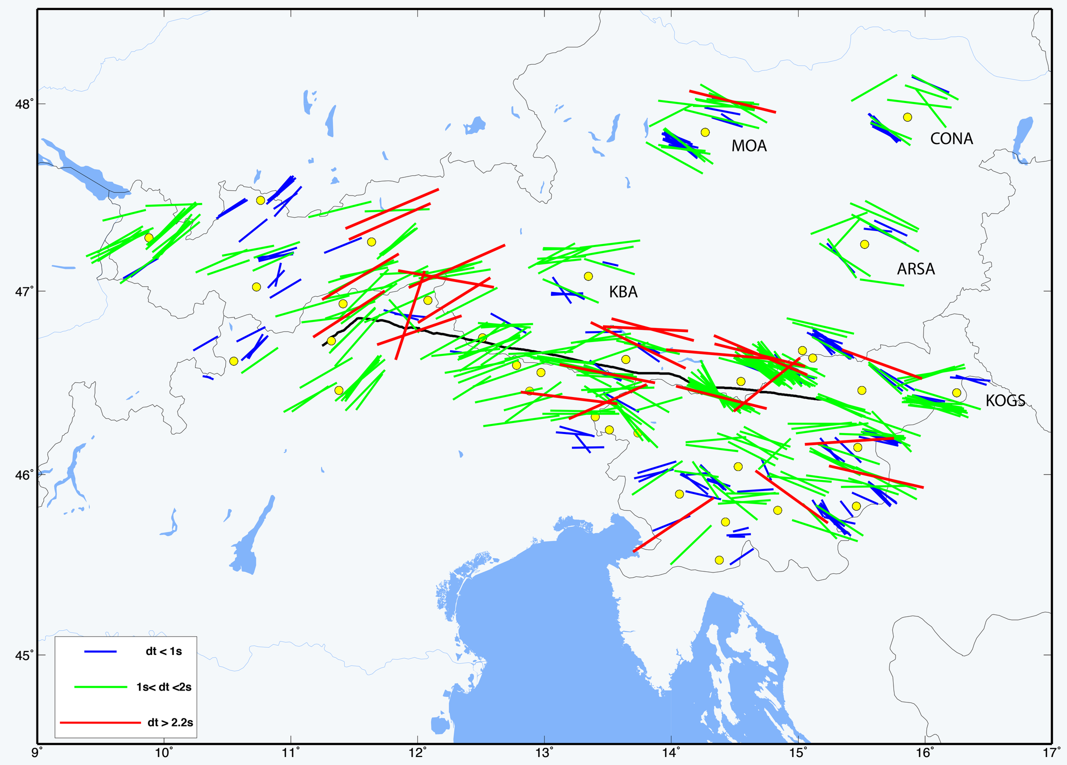
Individual measurements

The good quality individual splitting pairs, were obtained from different stations are presented in this Figure. We are able to divide the stations into two categories. Stations in the West show predominantly SW-NE fast orientations (blue vectors). In contrary, stations in the East present mainly NW-SE (red vectors) with a few SW-NE orientations at most of the stations (blue vectors).



Backazimuthal variation

In order to assess the backazimuthal variation of individual splitting pairs, we projected all good measurements back to the depth of 150 km along their ray paths using backazimuth and the incidence angle of SKS phases. As it is illustrated in this Figure.



Anisotropy along the Alps

How do the anisotropic parameters change along the Alpine chain?
We have projected the individual splitting pairs onto the center-line of the Alps that we have determined by connecting the centers of gravity of the mountain chain. Bottom figure: progressive rotation of fast orientations with the regions of constant fast azimuths in between. Variations of delay times along the Alps (top figure) occur at the same locations as the fast azimuths trend changes (point 1 ,2, and 3).