Automatic shear-wave splitting analysis with SplitWave

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Abstract

The AlpArray Project is a joint effort to adress questions about Geodynamics in Central Europe. An important property in this context is seismic anisotropy. Shear-Wave splitting can be used to study the anisotropy of the eart. Previous studies often did this in a semi-automatic manner. Barruol et al. (2011) for example could show, that fast splitting axes in the Western Alps are nearly mountain-chain parallel.

Many of the recent studies made use of the SplitLab package by Wüstefeld et al. (2008).

Here, we deploy the Cross-Correlation (RC), a Transverse minimisation (SC) and an Eigenvalue method (EV) from an open-source repository by Jack Walpole and compared these results with from the Chevrot-technique (2000).

This poster will show preliminary SKS-results from the Swiss permanent network and demonstrate the work flow for a single station. The goal is to establish a new automatic technique and apply it to the AlpArray network. The 600 stations recorded roughly the same amount of events as the permanent Swiss network did in 18 years.

Swiss Network and Events

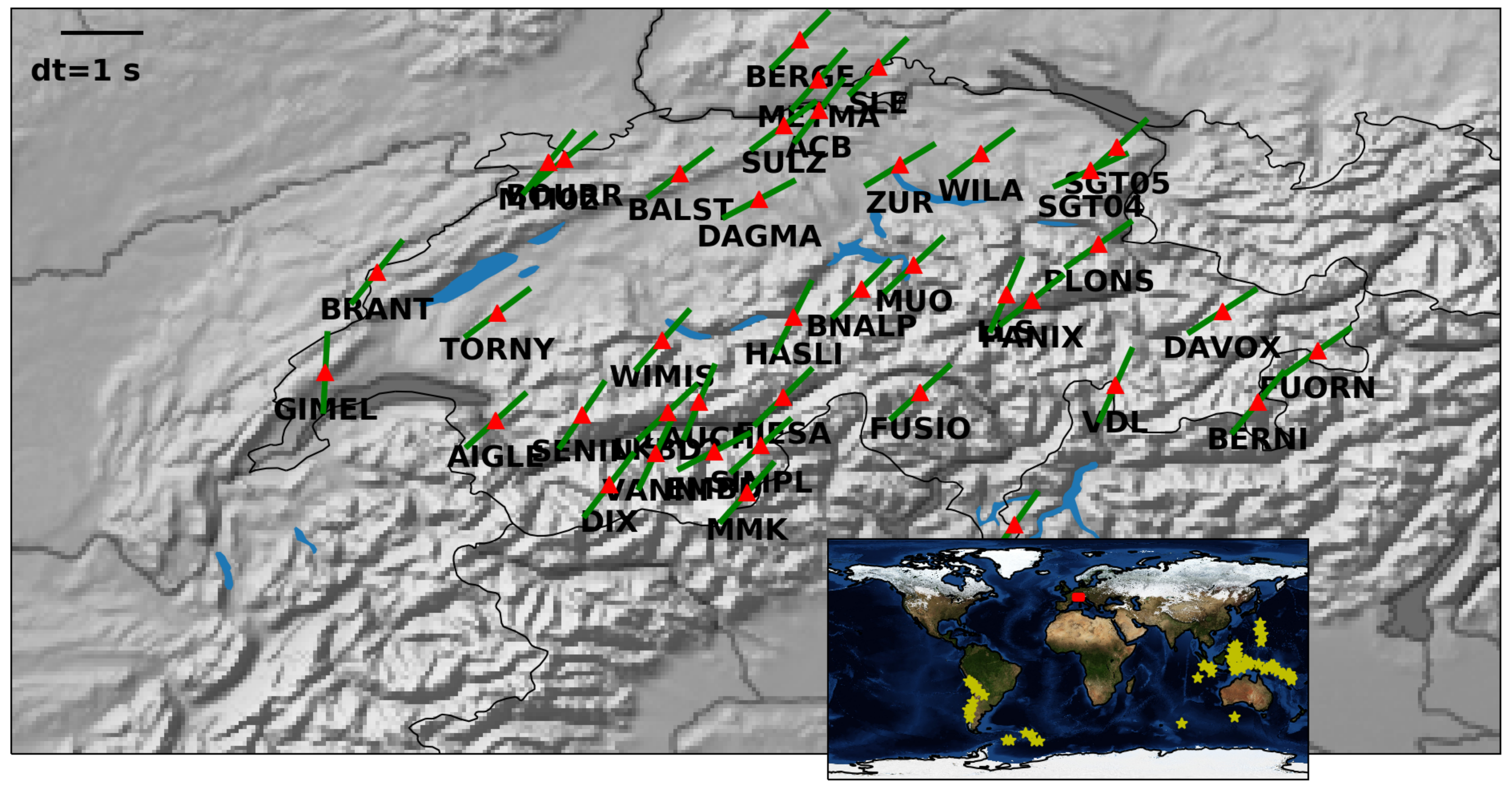
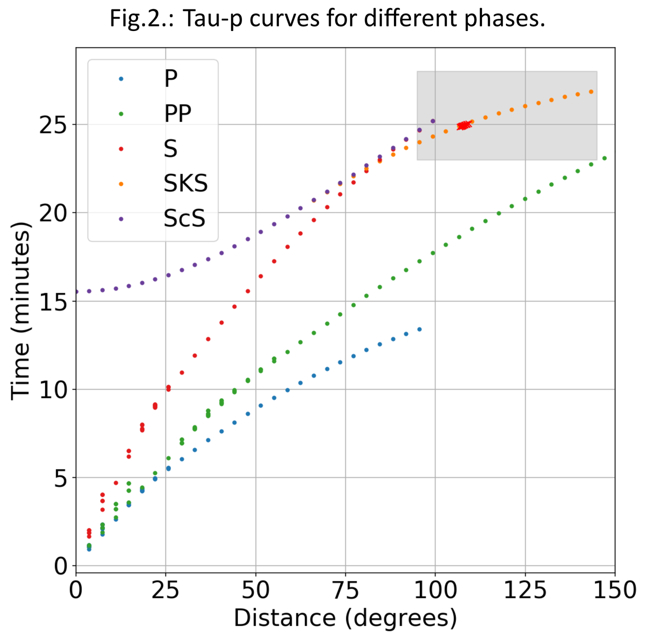


Fig.1: Preliminary splitting parameters (time lag and fast direction) of SKS-splitting from eq. 2 at permanent Swiss stations.

Key facts:

- Swiss permanent network: 40 Stations
- Time window between: 2000-2018
- Number of Events $M_w \geq 7$: 240
- Number of SKS-measurments: 3500
- Fixed time window around absolute maximum value $t_{win} = \pm 40$s

Fig.2.: Tau-p curves for different phases.



Shear-Wave Splitting

An effect of anisotropy can be observed in Shear-Wave Splitting of SKS waves from teleseismic earthquakes. These waves travel as compressive waves through the outer liquid core and when passing through anisotropic layers divide into a fast and a slow pulse. The fast direction and the time lag are the the parameters which are usually sought when carrying out Shear-Wave splitting measurements.

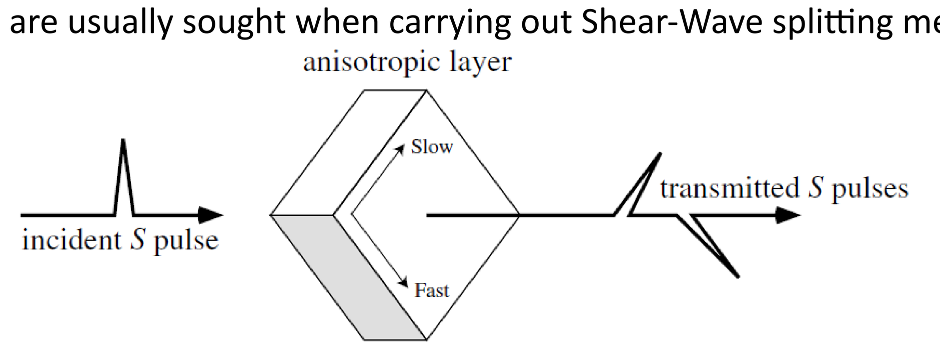


Fig.3.: Principle of S-wave splitting (Shearer, 2009).

There are different ways to obtain these parameters, e.g. the maximum cross-correlation (RC) method by Bowman and Ando (1987) and the transverse minimisation (SC) technique by Silver Chan (1991). These techniques allow determining fast direction and time delay for each station-event pair. The approach by Chevrot is somehow simpler. It assumes horizontal anisotropy and due to the similarity of components from the radially polarised SKS wave, it projects the transverse component (T) on the radial derivative (r) by a convolution with a splitting vector (s) (eq. 1). The splitting function describes the simple relation between the projected splitting intensities and the azimuthal event arrivals. This technique determines a single set of parameters per station, which is however relatively robust against low S/N ratios.

$$\mathrm{T}(t, \phi_R) = -\frac{1}{2}\mathrm{s} \circledast \mathrm{r} \tag{1}$$

where s varies as function of splitting time δt and the azimuth of fast axis ϕ:

$$s(\phi_R) = \delta t \sin(\phi_R - \phi) \tag{2}$$

SKS splitting and splitting intensity

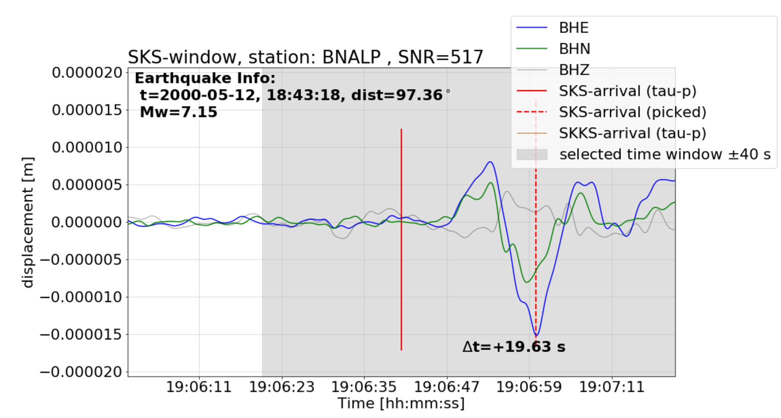


Fig.4: Example seismogram of an SKS-arrival.

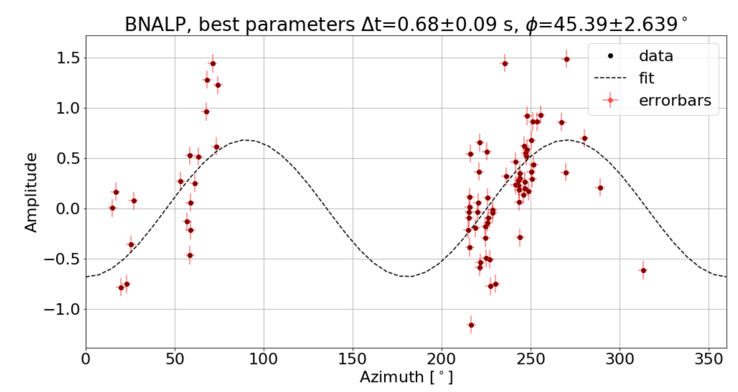


Fig.5: Splitting intensity plotted against the event azimuths together with best fit.

For each station, the algorithm performs a grid search over a solution space. The fitted sinusoidal function in Figure 5 indicates the best fit for the splitting intensities and gives a robust estimate for δt and ϕ.

Quality control

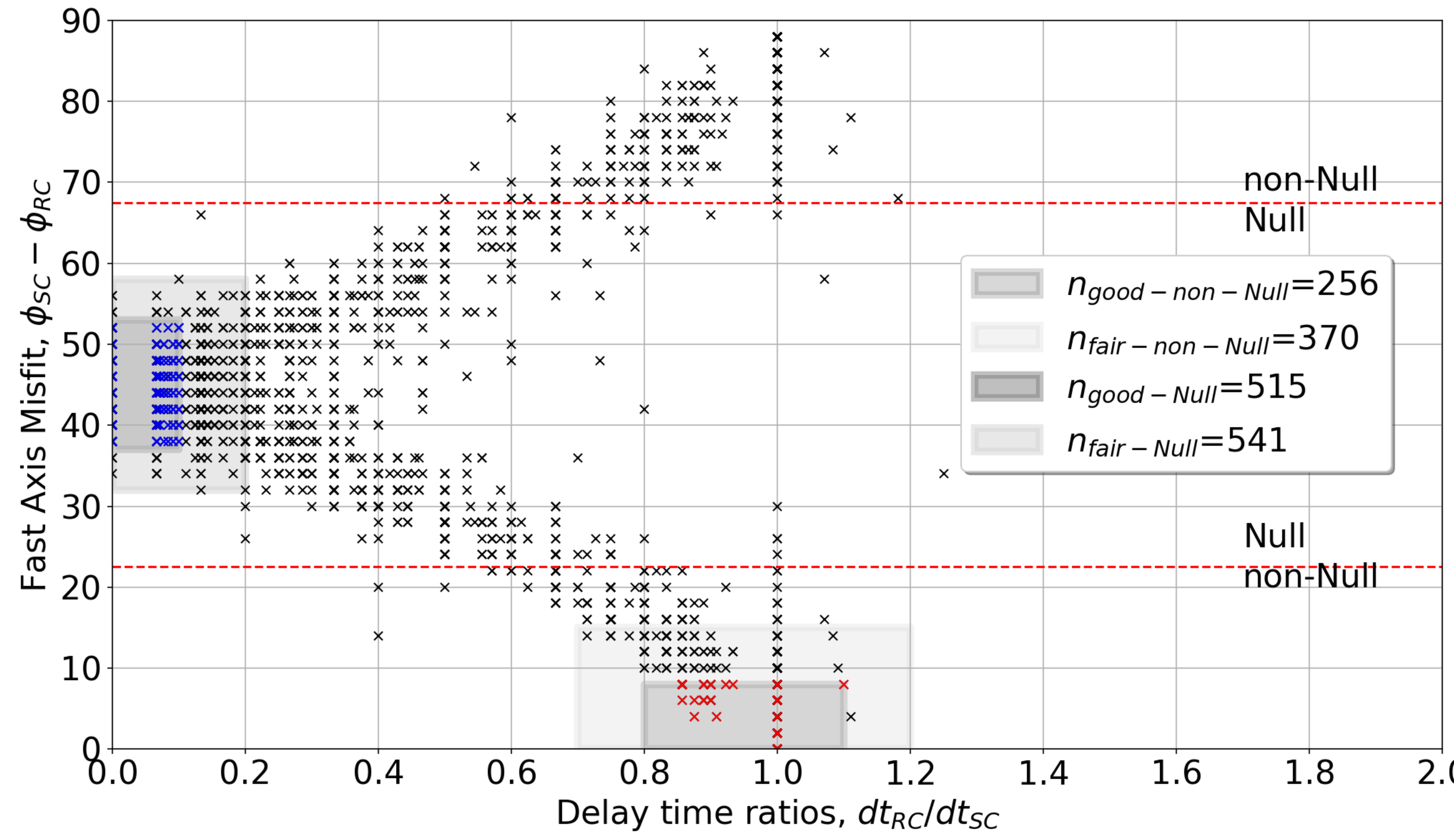
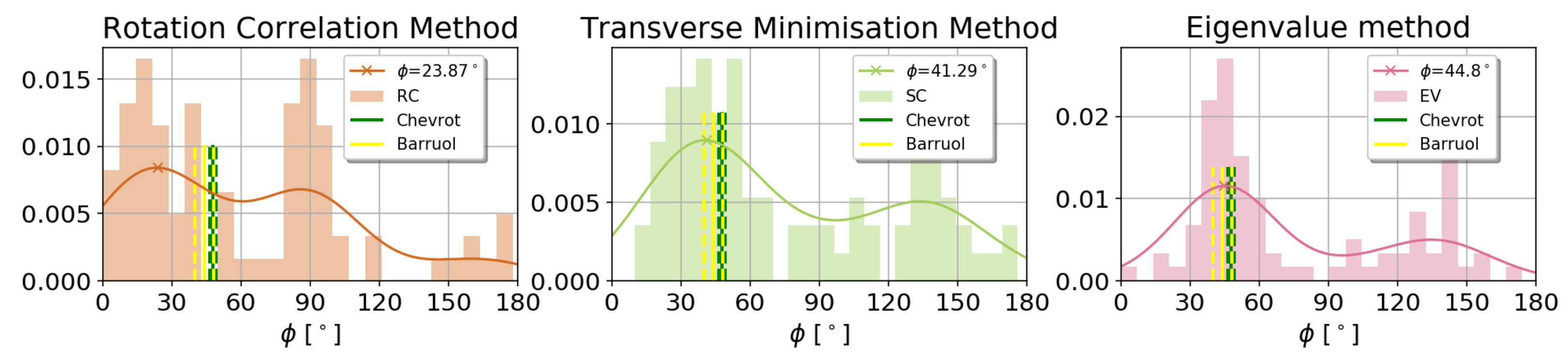


Fig.6: Misfit of delay-time and fast-axes between cross correlation method and the transverse minimisation method from Silver and Chan. The quality criteria were adapted after Wüstefeld et al. (2007).

Preliminary method comparison



Method	ϕ [°]	σ_ϕ	δt [s]	σ_{dt} [s]
Chevrot	47.79	1.45	0.96	0.08
Barruol	43.95	4.11	1.34	0.13
RC	40.00	22.78	1.03	0.39
SC	42.75	13.28	1.05	0.33
EV	43.00	14.28	1.378	0.36

Fig.7: Comparing fast axis results from SKS measurements by the different methods for station LLS.

Discussion and Outlook

- Relatively good agreement among methods. Manual results from Barruol can be reproduced.
- Still needs thorough quality inspection. More investigations about time and frequency window dependence of quality measurements.
- Future steps include a fully automatic Null detection, error surface stacking and a source-receiver correction.