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DC moment tensor estimation based on P- and S-waveform stacking

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Matching synthetic records to observed waveforms represents the most rigorous method to determine the complete focal mechanism of an earthquake. The recordings are usually filtered by band pass with an upper corner frequency of 0.03 - 0.05 Hz. The method has been successfully applied to earthquakes on global and regional scales. Currently, for a routine application the method appears to be limited to earthquakes $M \geq \sim 4$ because of the lack of signal in the low frequency range and the difficulty to appropriately calculate Green's functions in the higher frequency range. Alternatives restricted to the determination of DC-focal mechanisms are methods which match manually picked polarities of P- and S-wave arrivals. The result of manual polarity picking may become strongly influenced by the interpreter at magnitude $M < 3$. We present a method which is also based on the polarities of P- and S-wave arrivals, but avoids the subjective component of polarity picking.

We consider P-, SH-and SV-waveforms, band-pass filtered with a lower corner frequency just above the micro-seismic noise spectrum and weighting according to the S/N ratio. Filter design and the determination of the length of the waveforms (first two lobes) are done interactively. The polarity of an individual waveform is derived from the sign of the integral over the amplitudes of the first lobe minus the integral over the amplitudes of the second lobe. We produce three types of waveform stacks. The first stack ("crude stack") is simply the sum of the P- (or SH, or SV) waveforms. In order to generate the second stack ("maximum stack") we change the polarities of the individual waveforms to achieve a maximum objective function of the stacked traces. As objective function we choose the semblance times the difference of the integrals defining the polarity of a waveform. In case the brute and the maximum stacks are similar, the seismic source may have been an explosion. In case the objective function of the maximum stack is significantly higher than that of the brute stack we perform stacks where negative polarities of individual waveforms have been changed according to an assumed orientation of a DC-source ("DC-stack"). We calculate the objective functions for a dense 3D-grid covering all possible orientations of a DC-source. Waveforms from stations near the nodal planes get lower weights. We plot the objective functions at the positions of the corresponding T- and P-axes in stereographic projections for P-, SH-, and SV-waveforms and find optimum DC-stacks at the maxima of the objective functions. The plots show clearly the ambiguities of the solutions. Additional criteria are proposed to assess the quality of the optimum DC-stacks and to find an entire solution based on a weighted combination of the P-, SH- and SV- DC-stacks. The method has been successfully applied to several earthquakes $M < 3$ in and near the Vienna basin. Further testing and comparisons with conventional methods are necessary to evaluate the benefit of this new method.