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S-wave identification by polarization filtering and waveform coherence analysis

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The increasing number of seismic networks with high density of stations offers an ever larger amount of three-component recordings of earthquakes in a wide range of magnitudes. The analysis of these data can provide detailed information on both the propagation medium and the seismic source. In particular, the S-wave velocity is a key parameter for the understanding of the compositional and physical state of the lithosphere. On the other hand this requires a tool for identifying the seismic phase.

The S-phase can be identified by a change in amplitude and frequency content of the signal with respect to the P-phase. The precise identification of S-phase is generally made difficult by the intereference of P-coda waves, the arrival of converted phases generated beneath the recording site or the S-wave splitting. These factors can lead the operator to misidentify the phase or, very often, to abandon reading itself.

In this study, we propose a data processing technique aimed at univocally identifying the arrival-time of the S-phase by using three component recordings available at all stations of a seismic network. The proposed technique provides an additional support to the operators to be used for both the analysis of a single event or for the massive, quasi-automatic analysis of huge datasets.

The technique is based on the combination of a polarization detector mainly used in passive seismology and the move-out and stack analysis of trace gathers as for the velocity analysis in exploration seismics. The processing consists of four main steps. The first consists in P-phase picking and event location. The second step is the setting-up polarization detector: we rotate the three-component seismograms into the ray-coordinate system (L,Q,T), using theoretical backazimuths and incidence angles from P-phase polarizations. In the new system we calculate the directivity D, which is defined as the normalized angle between the P-phase polarization L and the actual polarization direction, the rectilinearity R and the ratio between transverse and total energy H. The product of the squares of the three filter operators yields the characteristic function (CF) for S-wave detection, with which we weight the transverse component traces. The third step deals with the seismic section analyses. Once the CF has been defined, the waveforms are displayed in common receiver gathers as a function of hypocentral distance. On each section we evaluate the lateral coherence of S-phase through a linear velocity analysis. The resulting S-wave velocity can be used to compute a reference pick for the S-phase at each station. In the fourth step an automatic picker is used around the reference value.

In the present study, we apply our S-wave detection-picking approach to a dataset of 5675 three component, ground velocity recordings of 626 local earthquakes with magnitude ML (0.1, 3.2), which occurred in southern Italy and were recorded by the Irpinia Seismic Network in the period December 2007 to March 2010.
To assess the performance of the proposed methodology, we compare the residuals of the automatic and the theoretical arrivals with the residuals between the manual readings and the theoretical arrivals. The dispersion of the residual distributions obtained from the refined picking is consistent with the dispersion obtained from the manual picks, while the total number of available readings is increased.