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Accurate seismic phase picking using High-Order Statistics: the case study of the Irpinia Seismic Array in Southern Italy

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Fault imaging and characterization of crustal structures, along with source parameter estimation, strongly depend on reliable direct seismic wave arrival times. To lower the detection threshold of small earthquakes and improve the quality of fault imaging, dense arrays of seismic stations are being installed more and more frequently in different parts of the world. Given the rising number of new, denser seismic networks and the growing demand for high-quality seismic catalogs, the use of automatic techniques is crucial to efficiently process and analyze the vast amount of seismic data, contributing to the advancement of seismic research and monitoring capabilities.

The Irpinia fault system (Southern Italy) hosted in 1980 the M 6.9 earthquake and is currently monitored by the Irpinia seismic network (ISNet), which is composed of 31 seismic stations covering an area of about 100x70 km^2 along the Campania-Lucania Apennine chain. ISNet was integrated by 200 seismic stations grouped in small-aperture arrays of 10 stations during the 1-year DETECT project (DEnse mulTi-paramEtriC observations and 4D high resoluTion imaging). DETECT focused on the acquisition of a unique multiparametric dataset and aimed to monitor and image the fault system during the inter-seismic phase fostering at the same time the collaboration among various institutions.

The use of seismic arrays, in a region characterized by high seismic hazard, presents a unique opportunity to introduce a novel technique that accurately reveals the first arrivals of seismic phases of small earthquakes. We examined 226 micro-earthquakes, with magnitude ranging from -0.27 to 2.28, detected by the seismic arrays during the first six months of the DETECT project (September 2021 - February 2022). We present a novel approach that utilizes high-order statistics (HOS), computed on the vertical components of waveforms, to identify P-wave arrival times and provide reliability measurements for our predictions. The advantage of the arrays' geometry enabled the integration of the HOS technique with a criterion designed to select the optimal onsets. The proposed methodology incorporated over 3,300 additional P-wave arrival times into the existing catalog. Furthermore, semblance measurements among traces recorded at the same array highlighted the superior quality of the selected picks compared to the existing ones.

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