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WaveLoc – an algorithm for the detection and location of seismic sources within large, continuos waveform, data volumes: the case of the L'Aquila earthquake sequence

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A big challenge of modern seismology is the analysis of very large data volumes of digital waveforms. Ad hoc techniques have been designed to analyze every byte of continuous seismological records (e.g., Green's functions determination from noise cross-correlation, earthquake and tremor detection). We present the results of the application to the L'Aquila earthquake sequence of WaveLoc - a back projection imaging technique that operates directly on the recorded digital waveforms without performing phase onset picking. The technique, based on earlier work by Withers et al. (BSSA 89, 657-669, 1999), allows for the detection and location of earthquake sources exploiting phase coherency. In order to enhance the first arriving P-wave energy, kurtosis pre-processing is applied to the recorded data. At each time step, cross-correlation between pre-processed data and simplified, pre-determined Green's functions (e.g., box-car centered at P- and/or S-wave arrival) is carried out. The values of the cross-correlation are summed onto a 3-D grid (x, y, t) of potential source locations placed at a depth consistent with the earthquake distribution. Earthquake occurrence is tested by summing the amplitudes to form the stack S(x, y, t).

Application to the data set acquired by permanent and temporary networks for the L'Aquila earthquake sequence during the first 25 days after the main shock, resulted in the detection/location of more 16,000 events with M>1.0. When compared to the events listed in the INGV bulletin, the technique has been found to detect nearly all the M>2.1 earthquakes and more than 80% of the events 1<M<2. In addition and at low magnitudes, the technique has been found effective in finding seismic sources otherwise undetected using standard procedures. On a 512 CPU cluster the procedure takes of the order of 40 minutes for the period analyzed which allows for repeated analysis using different detection and pre-processing parameter settings. Finally, the procedure appears well suited within a modular procedure aimed toward automatic, high-resolution earthquake location and it can be implemented in real-time.