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A comparative study of robust algorithms for rapid, automatic earthquake location

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The problem of reliable and accurate real-time seismic event location is a key issue in seismic event monitoring. Solutions of automatic earthquake locations and early warning systems are usually hampered by detrimental factors such as sporadic seismic noise, poor network configuration, heterogeneity of the Earth, incorrect phase association or multiple event manifestation. In the presence of large outliers, traditional earthquake location techniques based on a least-square misfit function (L2-norm) often yield unstable and unreliable solutions. In this study, we test the performance of two advanced earthquake location algorithms to compute more reliable earthquake location in the presence of large outliers: Network Beamforming (NB) and a non-linear probabilistic earthquake location algorithm using the Equal Differential Time likelihood function (NonLinLoc). We apply both methods to data of the Swiss Digital Seismological Network (SDSNet) encompassing two sets of arrival times: i) arrival times based on a simple STA/LTA trigger algorithm (trigger times), and ii) arrival times obtained by an automatic picking procedure (autopicks). At the SDSNet, arrival times based on the trigger algorithm are available within a few seconds after the origin time of the event, while arrival times obtained by the automatic picking procedure are usually available within a few minutes after the origin time of the event. To assess the performance of each method we compare earthquake locations obtained using the two sets of arrival times with their corresponding reference location, which we compute using arrival times picked by an experienced analyst. All earthquake locations have been computed using the same minimum 1D velocity model, except for the reference

locations, which we computed using a three-dimensional P-wave velocity model. For both methods, NB and NonLinLoc, 83 % of the epicenter locations based on the trigger times are within 10 km of their corresponding reference locations. For epicenter locations computed using autopicks the performance is similar for both algorithms and higher (93 %). Using a traditional L2-norm on the same data set, only 57% of the epicenter locations are located within 10 km of their corresponding reference location. The higher performance of automatic locations using autopicks is explained by its higher accuracy, e.g. less outliers. Our results demonstrate that both methods, NB and NonLinLoc, provide robust earthquake locations in the presence of large outliers. Our results further suggest that robust earthquake locations can be obtained using arrival times based on a simple STA/LTA trigger algorithm in combination with robust earthquake location algorithms, such as NB or NonLinLoc. This becomes important for rapid solutions since STA/LTA trigger times are usually available prior to arrival times obtained by an automatic picking procedure.